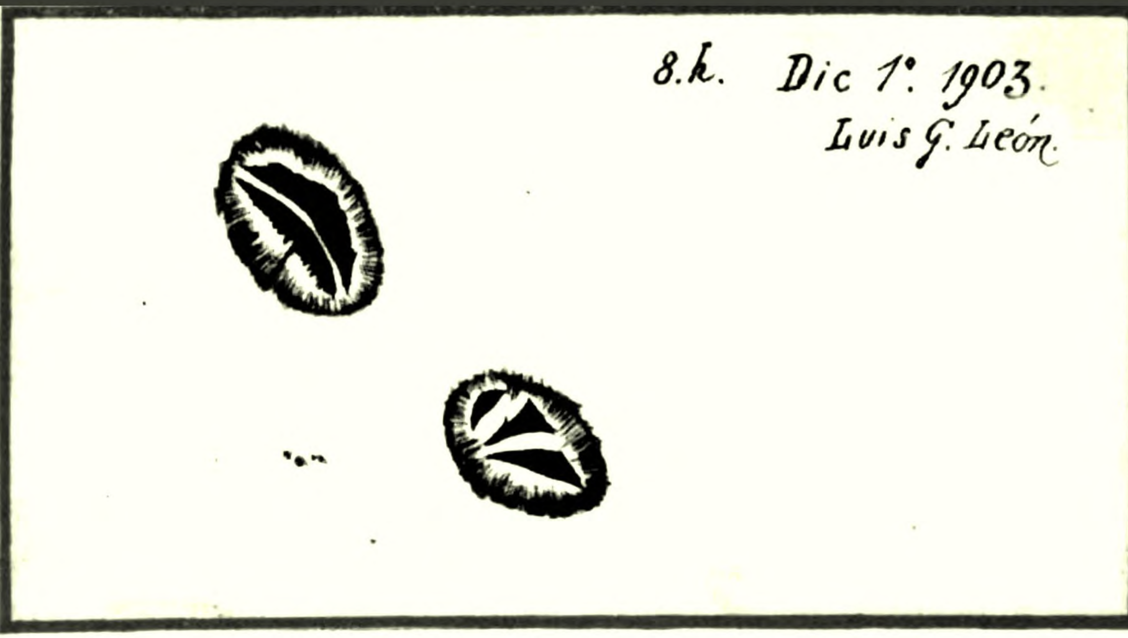

Popular astronomy

Carleton College (Northfield, Minn.). Goodsell Observatory

POPULAR

ASTRONOMY

PLAINLY WORDED AND LARGELY UNTECHNICAL IN LANGUAGE. AMPLY ILLUSTRATED.

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GENERAL INDEX TO VOLUME XII.

$17^h\,59^m$ — $20^h\,29^m$ G. M. T. $14^h\,57^m$ — $17^h\,34^m$ G. M. T.

BORRELLY'S COMET

1903 JULY 24th

The left hand photograph was made by R. J. Wallace.
Reproductions of the same plates were published in the Astrophysical Journal Oct. 1903.

Popular Astronomy.

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SOME PECULIARITIES OF COMETS' TAILS AND THEIR PROBABLE EXPLANATION.

E. E. BARNARD.

(Read before the Chicago Meeting of the National Academy, 1903 Nov. 18.)

Before the application of photography to the investigation of cometary phenomena the study of these bodies was beset with many difficulties. In fact most of the changing phenomena of the tails of comets were then wholly unknown and, hence, their study impossible.

The study of the physical condition of comets' tails may be said to have had its beginning in the past ten or twelve years. In that interval though no great comet has appeared, the photographic plate has faithfully portrayed some of the most extraordinary phenomena such as have to a great extent revolutionized our ideas of these erratic bodies. This, too, has occurred in the case of comets which with the older method of observing would have promised little or nothing of interest.

The remarkable phenomena presented by Swift's comet of 1892 were the beginning of these revelations. These were followed by similar appearances in Rordame's comet of 1893 as photographed by Professor Hussey.

But a new series of phenomena appeared in Brook's comet of 1893 which were suggestive of a wholly different explanation to those of Swift's and Rordame's comets. They suggested an outside influence foreign to the comet itself and of an extremely important nature.

The last comet sufficiently active to produce anomalous features was Borrelly's of the present year. This object, though it failed to fulfil the promises of a spectacular naked eye affair, showed a remarkable change in its tail on July 24 which will perhaps throw more light on cometary phenomena than any other comet has yet done. Though, unlike Brooks' comet of 1893, it suggested no outside influence, it yet presented an appearance that seems to offer itself to a satisfactory explanation, and which leads to a definite knowledge of the motion of the particles com-

posing the tail, and of the interval of luminosity of these particles when free from the comet.

In the case of Swift's comet a large mass of matter—several times larger than the head of the comet—was shown in the tail drifting back from the head. This seemed to be due to the separation of an unusually large portion of the cometary matter by the disruptive and repellant force of the Sun. Perhaps the most remarkable part of this phenomenon was that the mass looked like a secondary comet and had several tails of its own. From an inspection of the photograph it is clear that this object had its origin in the head of the comet, being simply a cloud instead of a stream of the repelled particles. Its system of tails was doubtless produced just as in the case of the parent comet, by the repellant action of the Sun.

The numerous tails frequently shown in the photographs of this comet (and in others since) were, it would seem, produced by different centers of emission in the nucleus of the comet—jets or streams of matter shot out from the different parts of the nucleus from different centers of activity.

According to the general theory of a comet's tail the action of the Sun upon the nucleus of the comet produces a repellant action in the nucleus on the sun-ward side and the particles thus expelled by the comet are met by the pressure of the Sun's light and driven back behind the comet to form the tail. This theory was sufficiently comprehensive to account for essentially all the visual phenomena of a comet's tail. But it does not satisfactorily account for the great number of thin diverging rays and thread-like streams shown by photography so often to be the main feature of the tail.

Indeed there are cases where a straight secondary tail or streamer makes a very large angle 45°—or more—with the main tail. It does not appear that the repulsive force of the Sun alone can account for this feature. And there are other peculiarities in the tails of comets shown by photography which rather suggest that a comet has more to do with the production of its own tail than has generally been conceded to it, further than simply supplying the material for the making of the tail.

Brooks' comet of 1893 presented phenomena unique in character and not susceptible of the explanation offered for the previous comet. Indeed the singular freaks of that comet's tail compel us to seek an explanation in some outside cause—inherent neither in the comet nor in the Sun. The tail which one day was in a normal condition, was on the next broken and disturbed as if it had

PLATE II

BROOK'S COMET

1893 OCT. 21 $0^h\ 35^m$ — $1^h\ 10^m$ G. M. T.

BROOK'S COMET

1893 OCT. 22 $0^h\ 37^m$ — $1^h\ 12^m$ G. M. T.

PLATE III

BROOK'S COMET

1893 Nov. 3d $0^h\ 0^m$ — $1^h\ 25^m$ G. M. T.

encountered some resisting medium in its flight through space. The disturbance seemed to come from the direction towards which the comet was moving. On the succeeding morning it was badly broken and hung in cloud-like masses, some of which were entirely torn off from the tail and appeared to be drifting away in space. On another occasion the tail was concave towards the direction of motion and had the appearance of beating against a current of resistence. It was disjointed in places, and near the end was abruptly bent at nearly a right angle as if at that point it had encountered a stronger current of resistence. If one examines these pictures there seems no escape from the conclusion that this comet's tail did actually encounter some resisting or disturbing medium about the 21st of October 1893 and for several days subsequent to that date, whether this was a swarm of meteors—such as we know exist in space near the Sun, or some sort of resisting matter of which we as yet know nothing is a subject for time to settle.

Photographs of Borrelly's comet on the night of July 24 showed a large section of the tail apparently completely broken off and displaced from the direction of the remaining portion of the tail, there was nothing in the appearance of this to suggest any outside disturbance. The section was straight and apparently uninjured. Other photographs made four hours earlier and three hours later showed that this section was receding from the comet and that the normal tail was growing in length. Determining the motion of the fragment from these photographs, it was shown that it must have separated from the head at 2:30 P. M., G. M. T. of July 24. Photographs of the comet on July 23 and July 25 showed nothing of this phenomenon.

The explanation of this feature appears to be a very simple one. It would seem that, for some cause, between two and three P. M. of July 24 there occurred a slight but sudden change in the direction of emission of matter from the comet. The first tail would then separate from the comet—as its supply of material would be cut off—and a new tail would begin in the new direction and grow to the normal length, while the section would drift out and dissipate into space. Thus would the phenomenon of July 24 be produced. The actual velocity of separation, determined from the photographs was 29 miles a second. As the comet was approaching the Sun at the rate of 22 miles a second, the real motion of the particles away from the Sun was 7 miles a second. This is a rather small velocity compared with some of those attributed to the particles composing a comet's tail.

This comet showed us that the tail actually moved out from the head as a luminous stream which remained visible for hours after its supply from the head had ceased. At the same time this section had a progressive motion laterally, which would partake of the original motion of the comet when the separation occurred. Let, therefore, this drifting stream encounter, say a dense swarm of meteors, or some other resistence and a disruption of its symmetry would occur—just as seems to have happened in the case of Brooks' comet of 1893.

This feature of Borrelly's comet seems to have been unusually well photographed both in this country and in Europe.

By a combination of measures of three photographs—the first at Nanterre, France by F. Quenisset, the second and third at the Yerkes Observatory by the writer and Mr. R. J. Wallacc, respectively, the following values of the hourly motion of separation of the tail from the head was obtained.

Nanterre and first Yerkes Observatory	plate 10′.1.	Interval	$4^h\ 35^m$
First and second " "	plates 10 .7.	"	2 59

The mean of these is 10′.4 for the hourly motion of separation.

I am convinced now that the slight difference between the above two values is due to the uncertainty of the measures. The small scales of the photographs and the ill-defined condition of the comet would not permit any closer agreement if the motion were uniform.

It appears therefore that there is no evidence of acceleration in the motion of separation. This is contrary to what would happen if the particles had been driven away from the comet by the repellant action of the Sun alone. For previous to its free existence the particle would be moving towards the Sun with a velocity of 22 miles a second—as a part of the comet. After it had become independent and subject to the repulsive action of the Sun, it would still approach until the repulsive force checked its speed, when for a moment it would become stationary and then begin to recede, at first slowly, and then with rapidly accelerating velocity. This would be its action if due alone to the repulsive force of the Sun—or the pressure of the Sun's light.

Assuming the correctness of the generally accepted theory of cometary tails, the want of acceleration in the motion of the fragment is puzzling, and would rather show that the Sun had little to do with its flight into space.

Some exception may be taken to the explanation I have offered for the cause of the phenomenon of July 24 in reference to the sudden change of the direction of emission of the particles from the

PLATE IV

SWIFT'S COMET

1892 APRIL 4^d — 5^d 23^h 25^m — 0^h 30^m G. M. T.

SWIFT'S COMET

1892 APRIL 7^d — 8^d 23^h 45^m — 0^h 35^m G. M. T.

head. It is only necessary however to examine the series of hpotographs of Swift's comet—or indeed of almost any other comet—to see that changes vaster than this rapidly take place in the form of the tail. One day it will be made up of a dozen thread-like strands, and the next of but one broad stream. Small divergent tails will form and rapidly die away and others spring forth in some other direction to take their place. I can see no objection to the supply of the main tail itself being suddenly stopped to break out afresh at some adjacent point producing a phenomenon like that of July 24.

The facts still remain however and there seems to be no other satisfactory explanation of them.

YERKES OBSERVATORY, November 1903.

THE WIDER FIELD FOR THIS MAGAZINE.

W. W. PAYNE.

This magazine has completed its eleventh volume, and the time has come for some important changes in its scope and the details of its general management.

Some years ago, when we advanced the idea of popularizing astronomy through the agency of a monthly magazine, some scholars of prominence said such a thing is impossible, others ridiculed the idea, and said it would belittle astronomy and so falsely set forth its great principles that the uninstructed would be misled, and the science would lose by means of such propagation as time went on. Still others took a middle ground, assuming that some work might be done in the way of popularizing astronomy by lessening the use of technical language which was then so common in most of the standard writings and in the formal treatises of the day; but, that part of the science which requires the higher mathematics for its proofs, its developments and its working theories, even these scholars held that it was very doubtful if this large and important part of the science could be popularized in the way we have suggested and maintain its integrity and preserve its unity.

We can now easily contrast the views of astronomers held a quarter of a century ago, which are briefly outlined above, with those more generally held now by workers in the various branches of modern astronomy. Then, the severe mathematical proof was the main thing which occupied the attention of the investigator, and too often his mathematics was such a cumbersome instru-

ment, or such a dull tool, that his work was slow, painstaking and inefficient. If one should ask for a translation of such work into a ready, clear and definite popular statement, it would not be a wonder if its author should hesitate to undertake such a task, or, refuse to do it because of the supposed or real impossibility of it. Now, our higher mathematics furnishes a very different system of logic from that in use a few years ago. Methods are abbreviated, proofs are more general and more easily acquired, and the needs of the older astronomy are nobly met by the present advanced state of pure mathematics. The scholars in its higher branches have done so well in modern times that astronomers are justly proud of them. They have little ground comparatively for complaint. They however need more help in some ways; for example, in the problem of three celestial bodies, so as to avoid the present tedious work of tabulating data for the predictions of the places of bodies moving in, or through, the solar system. There are some other things that might be mentioned which the astronomer would gladly receive from the hand of the mathematician to improve his method of work and to save him valuable time. But, the present state of the older branches of astronomy is such as to tend plainly to popular expression, for the benefit of hundreds of intelligent readers now, where formerly scarcely a single one could have been expected. Now, mathematical astronomers are writing stories for the magazines, in which the conclusions of science are employed, as the enticing data of the scientific imagination in clever plots that embrace the very end of the world in all the dread and scenic tragedy of its final destruction by fire. This is, indeed, an unexpected way of popularizing astronomy. We wonder that pictures of such vengeance should ever disturb the placidity of grave and venerable astronomers of the present day.

The new astronomy, so called, is even more effective in popularizing the modern phases of the science than the old, because its resources are so well adapted to that end. Its work is largely observational, both in physics and in astronomy, and its results, important and general, as they are, ean be easily stated, especially concerning that part of the science which depends mainly on the revelations of the spectroscope and the photographic plate. The great results to astronomy that have already come through the use of these instruments have made an epoch in the history of science, although their work is yet almost entirely in its elementary stage of advancement. The severer problems which the new methods will be called upon to solve are surely

coming, and some of them are already here, and they are sorely trying the patience and skill of the best scholarship both in mathematics and physics. We have only to think of what the spectroscopist is doing with the problems of motion of the stars and nebulous masses in the far-off stellar depths, to see what he must consider in regard to physical conditions before he can make safe predictions of their speed and mutual influences upon one another in free and constrained motion.

On the other hand the astronomer is using photography in many ways for making records of important astronomical data for preservation and for critical measurement. One of the most interesting features of this work that has been going on during the last two years pertains to the new planet Eros. Astronomers, in all parts of the world, hnve taken photographs of this little planet as it was rapidly travelling among the stars, on as many clear nights as possible, that they might know very exactly what path it *appears* to traverse in the sky, so as to compare this apparent path with the real path which is already well known. The difference between the real path and the apparent one will help the astronomer to tell how far the planet Eros is from the Earth, and when he knows that he can tell how far the Earth is from the Sun, he hopes, more accurately than he now knows. But in order to gain this knowledge, he must measure the distances of the planet from the stars as it passed by them, very carefully and very accurately, to make the plates worth anything at all, for finding its distance or that of the Sun; for the latter is already quite correctly known, the error being probably not more than 150,000 miles. In order to make this error in our knowledge of the Sun's distance certainly smaller it will require the very best work that the astronomer can do in the use of physical measurements and in the methods of reduction that require the severe use of the higher mathematics. We notice, very recently, that there is some difference of opinion in the minds of eminent astronomers concerning the way that the measures of these Eros photographic plates should be reduced in order to obtain the most accurate results from them. This is another instance in which mathematics applied to new uses, in different ways, may involve uncertainties that will prove harmful in some degree, we can not yet tell to what extent.

From the citation of these examples of the present condition of astronomy, old and new, it seems as if it were easily possible, now, to enter on a wider and more comprehensive range than heretofore in the treatment of astronomical themes in a popular

magazine like our own; and this number is only the beginning of this new venture. Other changes will follow as the plan is more fully developed.

Only a little more needs to be said beyond that which was indicated in our last issue respecting the larger field now open to this publication, and that will concern an important new feature that ought to make the magazine more largely useful than any of its predecessors have been. We mean the feature of a regular review of current astronomy. This phase of our science is weak everywhere. A critical review of the various publications of practical astronomy as they appear would certainly meet a need very generally felt, but nowhere faithfully and intelligently provided. The number of regular publications in particular branches of astronomy and the greater number of scientific papers of every kind that come to our book table every month are legion. That which we see or know about must be only a small part of the useful matter in constant circulation. What is most needed in regard to this condition of things is some means of sifting this continual harvest of literature, retaining for suitable record the worthy part of it, with proper credit, and justly criticising the useless and the vicious to lessen as much as possible its harm and its repetition. To carry out such a plan as this needs the aid of many specialists. One or two scholars can not do it alone, however able or willing they may be to undertake such a large and varied task. On the other hand the many, able astronomers that are now to be found in the United States could do such a work very easily if there were some plan devised by which each one should do only a little of that which he knows how best to do, the results from so many sources might be brought together in an orderly way that would mean much to many. Some such plan as this is now under consideration and will be carried into effect in the near future.

As already said some of the details of our wider plan have been suggested, by conversation and by letter, to many well-known and able helpers during the last month, and, it is a pleasure to say that happy and most encouraging responses have come to us from every side. More in detail will be given next time.

JESUIT ASTRONOMY.

JOHN SCHREIBER, S. J.*

FOR POPULAR ASTRONOMY.

PART I. THE OLD SOCIETY, 1540-1773.

In the following pages I have attempted to jot down a few notes concerning the Jesuits of the 17th and 18th centuries and their relation to astronomy: I say notes, because more than that these lines cannot claim to be; as a long sickness has prevented and still† prevents me from making them more complete, orderly and uniform.

It is certainly a great tribute, redounding to the honor of the Jesuits no less than to the fairmindedness of Professor Förster, Director of the Berlin Observatory, when he says in the *Viertel-jahresschrift of the Astronomische Gesellschaft*: "Amongst the members of the Society of Jesus in the past and in the present we find so many excellent astronomers, and in general so many investigators of purest scientific devotion, that it is of important interest to their colleagues in science to notice them etc.."‡

This portrayal by no means claims perfection or completeness for them, but it will probably show that the relation of the old Jesuits to astronomy was very heartfelt, very intimate and well cultivated, and that astronomy was treated in an anything but step-motherly way.

I speak exclusively of the old Jesuits, and understand thereby those who were members of the Society before its suppression. The Society of Jesus was founded in 1540, and was dissolved through the intrigues of the Bourbon courts in 1773. It is self-evident that beginnings were very modest, and the still not-numerous Jesuits so much occupied by their chief work, the application of their zeal to the salvation of souls directly, that scientific labors in the direction mentioned were not to be thought of. Hence the interval in question is narrowed down at best from 1550 until 1800, that is, to about 20 years beyond the Suppression, since many ex-Jesuits, who had received their education in the Society, lived and labored until about that time. Although

* "Die Jesuiten des 17. und 18. Jahrhunderts und ihr Verhältnis zur Astronomie" by Johann Schreiber, S. J., Assistant Astronomer at the Haynald Observatory, Kalocsa, Hungary. *Natur* und *Offenbarung*, Vol. 49, 1903.—Translated by William F. Rigge, S. J., Creighton University Observatory, Omaha, Neb.

† Father Schreiber, the author, died March 10, 1903.

‡ *Vierteljahresschrift der A. G.* 1890, page 60.

these studies were not their exclusive nor even their principal aim, they have nevertheless during these two and a half centuries been able to do valuable work.

Poggendorff's biographical dictionary of the exact sciences contains in its first two volumes the names of 8,847 savants from remote antiquity until 1863. Amongst these names which embrace many centuries, we find that a little more than 10 per cent are Catholic clergymen, a number by no means to be despised, when one reflects that the rest for the most part, as the notes about them prove, belonged to a profession which obliged them to do something in the exact sciences, such as engineers, professors of physics and mathematics, chemists, hydrographers, nautical men, and the like. And amongst the Catholic clergymen, who have done literary work in the domain of the exact sciences, the Jesuits again number over 45 per cent. So that among the great number of men of all times who have done literary work in the exact sciences, the Jesuits during the short space of 2½ centuries, figure up a very respectable sum, nearly 5 per cent.

It appears from De Backer's Bibliothèque des Ecrivains de la Comp. de Jésus, 1876, and with the aid of its annexed Table méthodique, that 217 authors have done literary work in astronomy specifically. This does not mean that all these productions were very excellent, but at all events it follows necessarily that in the Society of Jesus astronomy had by no means gone to sleep, but had developed a busy life, and as far as matters were destined to go, had blossomed to an ever-increasing extent. We may, of course, lay some stress upon the circumstance that in former times, when, as far as words are concerned, much less learning was required of individuals than today in our age of examinations without number and without end, the knowledge of the principles of astronomy was spread farther and more generally than now;* because almost all of those of the Society of Jesus who were engaged in astronomy, even those who were in any way prominent, took up astronomy so to say, out of private zeal, for they were primarily bound to attend to other functions, for instance, as professors of mathematics, philosophy, theology, or frequently as rectors of important colleges.

Astrology.

At the time that the members of the Society of Jesus began their astronomical activity, the status of astronomy was not well defined. Astronomus, astrologus and mathematicus were

* Dr. *Karl Kostersitz.* Über Bergobservatorien. Vienna, 1901.

very ambiguous terms. They might mean as well astronomer in our sense, as astrologer in our sense, that is, a savant, or a cheat as well, who has recourse to divination; or again in many cases both, a savant, who, while not exactly intending to deceive, was not able to emancipate himself completely from the views of his age, especially as divination was held in higher repute than true astronomy, and astronomers were in danger of starving to death, if they did not in addition dabble in astrology. This was the condition of affairs at the beginning of the 17th century. The good and great Kepler himself could not entirely escape this danger; he admits it himself: "This Astrology may be indeed a foolish little daughter: but, good God! where would her mother, the highly intelligent Astronomy remain, if she did not have this silly daughter. * * * And the Mathematicorum salaria are so meager that the mother would surely suffer hunger, if the daughter did not earn anything."

At all events Kepler seemed really to believe in astrology to some extent and not to indulge in pure deceit. Thus he once wrote a letter to Fathers N. Serrarius and J. Ziegler in Mayence, October 18, 1606; he sent them a work he intended to publish, and asked them for their opinion (for the Protestant Kepler was upon the best terms with the Jesuits) and said they should speak out their minds freely, he was not so sensitive * * *, at most they might pick a slight quarrel with him on account of astrology, but he believed that he was yet within the limits of the permissible.

In this weakness he had yet many models and colleagues of high-sounding names, such as Nostradamus, Regiomontanus, Stöfler, Melanchthon, etc.

With this astrology, the separation and removal of which from astronomy, was assuredly itself a meritorious work, the Jesuits were by no means on good terms. Already in 1591 Father Benedict Perrerius made a vigorous attack upon it. He wrote a work on the different kinds of superstitions, and very particularly "de divinatione astrologica." It went through five editions. In like manner Fr. Alexander de Angelis "In Astrologos conjectores" libri 5. Romæ, 1604. In the year 1676 the 7th edition entered upon the field. Fathers Roberti, Renaud, Pinamonti, Noceti, did similar work. Fr. Nicolas Caussin in 1649 published in the press a letter to a "personne illustre sur le curiosité des Horoscopes." The horoscope, that is, divining the character of a person from the positions of the stars at his birth, in other words, predicting —or mendaciously fabricating—his future fortunes, was,—I am

using the words of the Zürich Professor Wolf—"from the beginning a pure fraud and one most known to deceive," but one altogether indispensible to "personnes illustres." I draw attention only to Rudolph II, Wallenstein, Gustavus Adolphus, Catherine de Medici—; the 16th and 17th centuries could not exist without the noble art, astrology, so that Father Riccioli, in his famous work, the Almagest (I, 21) could say as late as the year 1651, that such people would always be found, and with Tacitus call them genus hominum "quod semper in Urbe vetabitur et semper retinebitur," only, he says, it ought to read in Orbe.* The fight against this superstition was certainly a deserving work.

Observatories.

The predilection for astronomy in the Society of Jesus stands out most clearly in the erection of observatories. I say, in the Society of Jesus—and truly as such; for this is not the affair of one man, let alone that of individual members of an Order not one of whom can dispose of a cent. Now the Society of Jesus has not only itself during its comparatively short existence erected a very considerable number of observatories, but was also in a condition to accept some of those that had been erected at government expense and to man them with appropriate talent.

Of course, the first observatories in which the Jesuits did work, were not observatories in the modern sense; this is true in general in regard to all the observatories of that time; they were only modest beginnings. There were proper sites, some necessary instruments, that were probably completed in course of time, some observers, and industry and zeal for science.

The first greater observatory which was fitted out by the Jesuits, was a government one,—built at the expense of the Celestial Kingdom,—in Peking, where astronomy had for ages past been held in high esteem, of course, more on the score of utility, in order to seek advice in all possible transactions, even the most intricate affairs of state, advice which the stars gave gratis very willingly, through speaking tubes, however, that did not always furnish their interpretation according to eternal laws. Nevertheless, we are indebted to the citizens of the Celestial Kingdom for

* v. Littrow says in his "Wunder des Himmels" (1886, p. 604), where he treats of these absurd things: "Whoever takes pleasure in these fairy tales, can find them in the works of the well-known Jesuit Riccioli (Almagestum novum)." Yes, certainly, but Riccioli communicates them "exaliorum magis quam Nostra opinione," and concludes thus: "Jam enim me taedet, in incerte Astrologorum pulvere lusum prolixiorem ludere," that is, it disgusts me to continue such low play. May this serve to complete, if not to correct, v. Littrow.

many very ancient, perhaps the oldest, observations. When the Jesuits were directing their steps towards China, astronomical knowledge was, of course, in a sorry plight, and it was time for a thorough reform. The intelligent emperor Cham-Hi then transferred the superintendency of the heavens to the Jesuits, their first task being to cut off with technical exactitude the cue of the Chinese astronomers which hung down heavily behind, and to offer them European fashions instead. It was a piquant coincidence, that contemporaneouslv with the erection of the Paris Observatory, Father Verbiest S. J. in Peking, in the Kingdom of the Centre, was equipping a sister institution in up-to-date European scientific style (1668). This observatory is the fourth of its kind of government institutions, as only the observatories of Leyden (1632), Copenhagen (1637) and Paris (1667) antedate the time of its erection. Fr. Verbiest was therefore the first director of the observatory, styled in Chinese the President of the Mathematical Tribunal, and from that time until the death of Fr. Hallerstein in 1774 a Jesuit always filled this position.

In order then to indicate briefly the activity of the Jesuits at this observatory, let me cite the passage from De la Lande's *Astronomia* (p. XXXIX) referring to it: "This observatory was not at all unprofitable; a great many good observations were made there, of which Fr. Gouye, in 1688 and 1692, published a part; and again Fr. Souciet a part in 1732; many of them also are to be found in the manuscripts of Mons. de l'Job. The Fathers Fontaney, Ricci, Gautil, Benoît, Jacque, Kegler, and Slaviczeck and many other Jesuits have distinguished themselves there." And in the *Memorias de Mathematica et Physica da Academia R. das sciencias de Lisboa*, Tom. II 1799, "Eclipses and occultations observed in Peking from 1753 until 1795 by Andreas Rodriguez." In like manner Hell in Vienna published in 1768 "Observat. astr. ab Anno 1717 ad annum 1752 Pekini Sinarum factæ etc."

Government Observatories.

Among the government observatories conducted by the Jesuits the following must also be mentioned:

Vienna. An observatory was erected there in 1745 as an annex to the university, but completed only in 1756. This was the beginning of the present university observatory. For it was reconstructed in 1820-1826 and in 1879 transferred to the Türkenschanze. A small observatory had indeed already existed in the Collegium Academicum since 1735 under the direction of Fr. Franz, but while a public one, it did not have the title of a uni-

versity observatory. The directors were Father Hell, 1745, and Father Triesnecker, 1792.

Wilna. The university observatory was founded in 1753. Fr. Poczobut restored it and completed the instrumental equipment, was appointed its director, and remained even after the Suppression in the same position and with the same staff of observers, as the most of them were ex-Jesuits.

Schwetzingen 1764 and *Maunheim* 1772. Built by the Elector Theodore of Palatine; Fathers Christian Mayer and John Metzger especially worked there.

Private Observatories.

Outside of these government institutions the Jesuits possessed also many observatories erected with their own funds. I mention only the most prominent.

Marseilles. In 1702 the Jesuit college of S. Croix erected a small observatory, at which amongst others Fr. Lavel and later Fr. Pézénas observed.. Fr. Pezenas equipped it richly with instruments, mostly at his own cost, and obtained a pension from the queen in order to support two Jesuits as assistants. He himself was director until the Suppression of the Society. This scientific institution was taken in charge by the Administration of Marine in 1749, but the Jesuits remained there.

Lisbon (1722). Founded in the college of St. Anthony, it was taken in charge by the government in the year 1728, and transferred to the royal palace. The first director was Fr. Carbone S. J.

Prague. The modest observatory existing already was completed by Fr. Jos. Stepling, and equipped by him with new instruments at the expense of the Bohemian Province of the Society of Jesus; in 1761 Fr. Stepling also devoted to the observatory the inheritance of 4,000 florins coming to him after his mother's death. He increased the library of the Clementinum (so the enormous College of Prague was called) by about 600 of the best mathematical works, so much so that a section was called the "Mathematical Library." He directed this observatory from 1751 until his death in 1778. After the Suppression it became and is still the government university observatory.

Vienna. At first the beginning of an observatory existed under the title of "Mathematical Cabinet," in the erection of which the greatest credit is due to Fr. Ernest Vols. He died in 1720. The academic college possessed some instruments since 1735, which were used by Fr. Franz. This private observatory still continued

after the erection of the university observatory in 1745. Fathers Liesganig, Pilgram and others were especially prominent at this observatory.

Milan. Fr. Pascal Bovio and Fr. Dom. Guerra, professors of philosophy in the college of Brera, erected in 1760 an achromatic telescope of 40 feet focus, and also an armillary sphere and a pendulum clock, and thus founded an institution which must be considered as the origin of the present observatory (Obs. di Milano). The need of finer measuring instruments was soon seen, and the rector of the college, Fr. Pallavicini, a man very enthusiastic for science and himself very learned, provided some instruments. In 1762 Fr. Lagrange, already renowned through his labors in Marseilles, became director. Then Fr. Boscovich, called by the senate of Milan to be professor of mathematics at the Pavia university, came to Milan, managed the erection of a more suitable observatory, and acted for a while as director. After him came Fr. Lagrange again. The Jesuits had spent 60,000 livres on the observatory.

Florence. Fr. Leonhard Ximenes, who had won great renown for himself especially in hydraulics, was commissioned by the emperor to settle the boundary difficulties between Toscana and Lucca. No question in hydraulics was treated in Italy without being submitted to him. He applied the means coming to him from his father's fortune and his own various official positions, to adorn Florence with a scientific institution. He founded the observatory of S. Giovannino, renowned for its great mural quadrant and the famous gnomon of Toscanelli, which Ximenes restored. He added an excellent library and a large number of instruments. After a pious and laborious life he died at the age of 70 years in 1786. In his will he founded two professors' chairs, one for astronomy, and the other for hydraulics, which were to be filled by two Piarist religious priests, to whom he also deeded his library and his cabinet.

Rome. "Observatorio di Collegio Romano,"—which however no longer belongs to the Roman College, but along with all its valuable instruments was acquired by the government in 1870 in a very profitable and cheap way, that is, was declared to be government property, an act which, of course, settled the question of justice. The beginnings of this observatory date far back. The buildings of the Roman College which were erected in succession at various times, have for a long time back given shelter to astronomical instruments. In the old Roman College Fr. Scheiner gathered the material for his chief work Rosa Ursina, in which he

exhaustively treats of the science of the Sun as known in his time, and used there the first telescope mounted equatorially. The same building saw the labors of Fr. Clavius, who observed with a zenith sector as early as 1572, of Fathers Grienberger, Gottigales, Asclepi, Borgondi, Boscovich, and many others. A more suitable place was being projected for the observatory, but the Suppression of the Society put an end to these plans. In 1824 the observatory was again given over to the Society, and under de Vico, Sestini and Secchi it became a modern observatory equipped with the best instruments, at the expense partly of the Society, and partly of the private means of Piux IX. But this date already transcends the time limits marked out in this paper.

Parma. In 1757 Fr. Belgrade allowed one of the two towers of the college in Parma to be changed into an astronomical observatory.

Pout-à-Mousson was provided with a good observatory and equipped with very good instruments. Here amongst others Fr. Collas, who went to India in 1767, and Fr. Barlet, observed a partial eclipse of the Sun, which the Paris astronomers had neither predicted nor announced. The details of this observation were given in all the papers of that time.

Graz. The new building of the astronomical observatory was begun in 1745: the college contributing 7,000 and the Provincial of the Order 2,000 florins. The Jesuits did very much for this observatory, as for instance, establishing a special fund for its maintenance, which amounted already to 4,300 florins in 1773. Here Fr. Liesganig determined the meridian of Graz, Fr. Tirnberger discovered the comet in 1769, and Frs. Bode and Biwald worked. Things went on in this way until the Suppression of the Society, and then?— Then it was judged proper to do away with the chair of astronomy, to lock the observatory, to give over the capital to the students' fund, and at the very end in 1787 to tear down the mathematical tower—under the plea of "unnecessary."

Lemberg. Von Zach, who was by no means a special friend of the Jesuits, writes in regard to the Lemberg Observatory:* "It is a pity that at a time, when the science of the stars is obtaining new protectors and warm promoters in all countries, already existing institutions, which might advance this science, should go to ruin or be neglected. While the Order of Jesuits was still in existence, the Lemberg College had in connection an observatory which was pretty well provided with various astronomical in-

* Monatl. Korrespondenz von v. Zach, Nov. 1801, p. 547.

struments. * * * Later on this astronomical tower was entirely demolished, so that no trace of it is left any more. * * * There was no dearth of pendulum clocks, and amongst them a fine English one by Graham. * * * These clocks are scattered amongst the various professors and serve as ornaments to their rooms."

Tyrnan. The observatory in Tyrnan in Hungary was erected in the years 1753-1755 in the great college there with which the university (now in Budapest) was connected. The observatory was 110 feet high, the observing tower attached to the building 18 feet high, 56 feet long on the longer side and 40 feet wide on the shorter, and provided with an underground space 12 feet deep, which was intended especially for the comparisons of the baroscope and thermoscope above and below. It was built under the direction of Fr. Francis Weiss, who was appointed the director, his assistants being Fr. John Sajnovits and Fr. Francis Taucher. At the time of the Suppression of the Society the observatory had a small fund of 2,290 florins; at the Suppression things were managed with greater forbearance than they were for instance in Graz and Lemberg, as the government desired the observatory to continue, and even promised to defray out of the university treasury what was necessary over and above the 120 florins of the interest of the above capital. Of course, the confiscated property of the Jesuits was more than sufficient for this purpose. Fr. Weiss remained the director and professor of astronomy at the university, the former assistant at the observatory remained in his position with a salary of 600 florins. Fr. Weiss' (1717-1785) astronomical observations and treatises had spread his name in astronomical circles even in foreign countries, according to the assurances of the royal commissaries in 1774. He was also invited by the Elector to the Mannheim Observatory, but he declined.

This would finish the enumeration of the most prominent observatories; for there were others also of lesser importance concerning which I could not get more particulars, as Breslau, Olmütz, Ingolstadt, Dillingen, Toulon and others.

Astronomical Inventions.

Let this suffice for the observatories. Now only a few words about three contrivances which figure very prominently even at present in all observatories, and which owe their existence to three Jesuits. The first is the vernier. Probably not a single astronomical angle-measuring instrument, not a theodolite, not a

universal instrument, not an equatorial, is to be found unprovided with verniers. It consists essentially of two scales, moving upon one another, and so arranged that when one of them, for instance, is divided into degrees, the other has 10 divisions corresponding to 9 degrees of the first, and in this way reads to tenths of a degree. The inventor is Fr. Christopher Clavius. (Famous mathematician, died 1612 in Rome).

Brensing writes as follows in his article "Nonius or Vernier" in the *Astronomische Nachrichten:** "Clavius has been forgotten or neglected in an unintelligible way; I was surprised when I came upon the following passages in his works (Christophori Clavii Bambergensis opera, Moguntio 1611):" —he cites in full—; and then continues: "These passages give the clearest proof that we are indebted to no other than Clavius for the theory of vernier subdivision, as well for linear as for circular measurements. They have been overlooked." Professor Wolf of Zurich thinks that this contrivance should be called neither Nonius, nor Vernier, (the assigned inventors) but rather Clavius.

The second contrivance to be found in all observatories is the equatorial mounting of the telescopes, which, when they are of a certain size, are then simply called equatorials. The arrangement consists in turning the telescope about an axis which is parallel to that of the Earth, so that when the telescope is perpendicular to this axis it moves in the plane of the equator, when it is turned up or down, it always moves in parallel circles, thus enabling one always to keep a star in the field of view without difficulty, when once the tube has been set upon it. The invention of this important contrivance is derived from the Tyrolese Father Christopher Grienberger (died 1636 in Rome). Fr. Christopher Scheiner says in his chief work, Rosa Ursina, p. 352, that Fr. Grienberger endeavored to invent this mounting for the special purpose of making daylight observation of stars possible. The first observation with this kind of mounting of which we can find a record, was made on March 4, 1627, by Fr. Scheiner, who used it for his solar observations, "because, he says, although Fr. Grienberger has lately constructed this machine for other purposes, it is specially suited for my work." He adds also that he describes the machine "because, as it seems, the inventor of this instrument will not do it himself." Thanks therefore to Fr. Scheiner that it was not forgotten on account of the modesty of the inventor, or connected with another name, as happened to the vernier of Fr. Clavius

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* *Astr. Nach.* Vol. 96, p. 131.

which was brought to light and ascribed to its inventor only after 270 years.

But Fr. Scheiner also here deserves a mention. I will not speak of his inventing the pantograph, so generally used today, and that too in both of its styles, because it does not strictly belong to astronomy. It has been proved that in order the better to observe sun-spots he constructed the first *astronomical* telescope, that is, one consisting of convex glasses exclusively in opposition to the only one hitherto used, called the Dutch telescope, which had both convex and concave glasses (1613), the advantages of his being such that it later on almost entirely superceded the Dutch telescope.

The idea of the reflecting telescope also comes from a Jesuit. The thought of replacing the objective lens by a mirror was announced as early as 1606 by Fr. Nicolas Zucchi (Parma 1586—Rome 1670), and carried out at least in so far that he took the image made by a concave mirror and examined it with a concave lens.

Another important invention, which I would put down as the third, and which is continually being used even at present, especially in observing comets or other such objects which do not admit of artificial illumination in the field of view of the micrometer of the telescope, was the happy idea of Fr. Roger Joseph Boscovich (Ragusa 1711—Milan 1787) of using the circular field formed by the last diaphragm in the telescope as a micrometer—called a ring micrometer. The ring micrometer is often ascribed to Huygens, but, as Wolf* shows, falsely so. The field of view of the telescope was, of course, being used for measuring the diameters of the planets, a method which appears already in Fr. Scheiner; Huygens added a contrivance to this to facilitate this measurement. But this was no ring micrometer in the present sense, by means of which the difference of position of two stars is computed from the times of their ingress and egress. It was an occasion of the comet of 1739 that Boscovich showed it was exactly in comparing such an object, which scarcely admitted of a field illumination, with a neighboring star, that the observation of the times of entering and leaving the field of view of the telescope furnished the data for computing the difference of right ascension and declination, and he developed the appropriate theory. This ring micrometer was later on fitted up by Frauenhofer in excellent shape, so much so that now it occupies a place among

* Wolf, *Handbuch*, Vol. II, p. 128.

the instruments of precision of every observatory, and in the observation of comets it is used almost exclusively.

(TO BE CONTINUED.)

THE CREIGHTON OBSERVATORY, OMAHA, Neb.

THE RELATION OF THE MASS OF THE UNIVERSE TO STELLAR DYNAMICS.

LUIGI D' AURIA.

FOR POPULAR ASTRONOMY.

Supposing the stars to be scattered without any great and well-marked deviation from uniformity and to constitute a system approaching the form of a sphere of some finite radius ρ, the acceleration or retardation upon any one of the stars caused by the mass M of the *ensemble* would not differ much from that produced upon a material point occupying the place of the star by a sphere of gravitational medium of radius ρ and uniform density

$$\sigma = \frac{M}{\frac{4}{3}\pi\rho^3} \qquad (1)$$

In other words, on this supposition, we could study the dynamics of the stars by considering these bodies as material points moving in a hypothetic uniform medium having for density the value of σ given above.

In a paper entitled "Stellar Dynamics," read May 13, 1897, before the American Philosophical Society of Philadelphia, published in the *Journal of the Franklin Institute*, Oct., 1897, I showed that the acceleration of a body contained within a sphere of gravitational medium of uniform density σ, at any distance x from the center of this sphere, would be

$$\phi = g\frac{\sigma x}{RD} \qquad (2)$$

in which R and D are the mean radius and the mean density of the Earth, and g is the mean gravitative acceleration at the Earth's surface. In this paper the effect of the mass of the stars was neglected, that is, the stars were considered simply as material points attracted by a sphere of gravitational medium of uniform density σ extending to the boundary of the stellar universe, and it was shown that, if devoid of angular motion, a star under these conditions would oscillate in a straight line passing through the center of this sphere with velocity

$$u = \sqrt{\frac{g\sigma}{RD}(a^2 - x^2)} \qquad (3)$$

in which a is the initial distance of the body from the center of the sphere, and x its distance at the instant of time considered.

If the body had been subjected to a tangential impulse, it was shown that it would revolve in an elliptical orbit around the center with velocity

$$u = \sqrt{\frac{g\sigma}{RD}(a^2 + b^2 - z^2)} \qquad (4)$$

in which z is the distance of the body from the center, and a and b are the semi-diameters of the ellipse. When the body revolves in a circular orbit of given radius a, we have to put $z = b = a$, and we get

$$u = a\sqrt{\frac{g\sigma}{RD}} \qquad (5)$$

that is, the same value which is given by (3) when $x = 0$, showing that the velocity of a star moving in a circular orbit is the same as that which the star would acquire in falling radially to the center of the orbit.

The period of revolution was found to be the same for any orbit irrespective of its dimensions, which period is expressed by

$$T = 2\pi\sqrt{\frac{RD}{g\sigma}} \qquad (6)$$

The amount of kinetic energy of translation of all the stars at any instant of time, supposed to be moving in various elliptical orbits, may be represented by

$$W = \frac{1}{2} v_0^2 M,$$

in which v_0 is the mean speed of stellar motion. As the mean stellar distance is $\frac{3}{4}\rho$, we may represent the maximum possible amount of kinetic energy of the stars by the product of $\frac{1}{2}M$ by the square of the velocity acquired by a star falling from this distance to the center of the universe, which product is

$$W_1 = \frac{1}{2} M \left(\frac{3}{4}\rho\right)^2 \frac{g\sigma}{RD}.$$

Now if the stars were all moving in circular orbits we would have $W = W_1$, because then all the energy of the stellar universe

would be kinetic. If the stars were all moving in straight lines passing through the center of the universe, the energy would be half kinetic and half potential, and we would have $W = \frac{1}{2} W_1$. Averaging between these two extreme cases, we can put $W = \frac{3}{4} W_1$, or

$$v_0^2 = \left(\frac{3}{4}\right)^3 \rho^2 \cdot \frac{g\sigma}{RD} \qquad (7)$$

from which we get

$$\sigma = \left(\frac{4}{3}\right)^3 \frac{v_0^2}{\rho^2} \frac{RD}{g} \qquad (8)$$

Comparing with (1) and solving for M, we find

$$M = \left(\frac{4}{3}\right)^3 \frac{v_0^2\rho}{g} \cdot \frac{4}{3} \pi RD = \left(\frac{4}{3}\right)^3 \frac{v_0^2\rho}{gR^2} \cdot \frac{4}{3} \pi R^3 D,$$

and observing that $\frac{4}{3} \pi R^3 D$ = mass of the Earth $= E$, we can write

$$M = \left(\frac{4}{3}\right)^3 \frac{v_0^2}{gR} \left(\frac{\rho}{R}\right) E \qquad (9)$$

This formula, though not absolutely exact, is perhaps as close as the problem in question will ever allow us to go in the determination of the mass of the universe when the radius ρ and the mean speed of stellar motion v_0 are given.

The mean speed of stellar motion, according to the researches of Kapteyn, is $v_0 = 102,000$ ft. per second, and with this value, and the numerical value of gR in feet, we get

$$M = 36.7 \left(\frac{\rho}{R}\right) E \qquad (10)$$

Assuming for ρ the distance corresponding to the parallax of $0''.001$, or $\rho = 4.8 \times 10^{12} R$, we get

$$M = 1.76 \times 10^{14} E \qquad (11)$$

and, in terms of the Sun's mass S, we would get $M = 530,000,000\,S$.

Putting the above value of ρ and the value (11) of M in (1), we get $\sigma = 1.58 \times 10^{-24} D$, and with this value of σ the period of revolution of any star is found to be $T = 4 \times 10^{15}$ seconds, or about one hundred and five million years. Thus a star starting from rest from any point within the universal sphere would reach

the center of the universe after a time $\frac{1}{4}T$, or about twenty-six million years. A body placed originally at rest upon the boundary of the universal sphere would at the end of this time acquire a velocity of about 30 miles per second, which would be the maximum velocity of a star moving within this sphere.

As there are some stars possessed with speed much higher than this, and in the case of 1830 Groombridge, as high as six or seven times the above maximum, we must admit that either these stars have entered our universe with velocities of their own, or that there is a gravitational medium extending far beyond the sphere of the stellar universe, since a body, even if attracted to the boundary of this sphere from an infinite distance, could not attain a velocity higher than 1.4 x 30 = 42 miles per second. Now, if we adopt Newcomb's star density derived from stellar statistics, there would be in the sphere of radius ρ about 125,000,000 luminous stars, and, if we assume an equal number of dark stars, we would have in all 250,000,000 stars. Thus if the average mass of a star were equal to the Sun's mass, the density of the medium in question, if uniform, could not be greater than $\sigma_0 = \frac{1}{2}\sigma$, or say, $\sigma_0 = 8 \times 10^{-25} D$, which, in terms of the density d of atmospheric air, would be

$$\sigma_0 = 3.4 \times 10^{-21} d \qquad (12)$$

With this density the medium would have to extend to at least nine times the assumed radius of the stellar universe in order to hold 1830 Groombridge within its boundary and account for the great velocity of this famous star.

As it seems very unlikely that the average mass of a star could be less than the Sun's mass, we must consider the above value of σ_0 as the superior limit of density which a universal gravitational medium of uniform density could have if it actually existed. This limit of density is about 165 times smaller than the major limit of density assigned by Maxwell to the ether. Hence, Maxwell's major limit of density would be inadmissible if the ether were gravitational.

The common period of revolution for all the stars found above shows that, on an average, it would take a century for a star to describe an arc of 1″.2, and this is in accord with the fact that the proper motions of the stars since they were first observed show no appreciable curvature. This fact allows us to consider the projection of the proper motion of any star as that of the direction of the tangent to any number of plane curves of large

dimensions passing through the point occupied by the star, and therefore, however bewildering the projections of the proper motions of the stars may appear to be, we can always imagine them to be the projections of proper motions performed in various elliptical orbits having a common center. Hence, the fact that the position of this common center cannot be divined from the general arrangement of these projections, does not, as some astronomers have thought, conclusively disprove the idea that the stars are moving in orbits and constitute a system.

Concerning the position of the center of the universe, the quasi-symmetrical arrangement of the stars with respect to the plane of the Milky Way makes it very probable that this center is located in this plane. Now if we accept Kapteyn's estimate of the Sun's motion, about ten miles per second, we might account for this velocity by supposing the Sun to be moving in a circular orbit of radius $\frac{1}{3}\rho$, the corresponding parallax of which is 0″.003. But, so far as we can judge from the enumeration of the stars in all directions, and from the aspect of the Milky Way, our system is near the center of the stellar universe. We must conclude, therefore, that our Sun is moving in an elliptic orbit of large eccentricity, and is now near the minor semi-diameter, whose length is a small fraction of $\frac{1}{3}\rho$, which represents the length of the major semi-diameter of the orbit. Thus if the ratio between these semi-diameters were ten, the distance of the Sun from the center of the universe would be about $\frac{1}{30}\rho$, the corresponding parallax of which is 0″.03, but, for all we know, the Sun may be moving practically in a straight line and be passing through the center of the universe. All we can say from the results of our calculations is that the Sun's excursions in space are performed within a sphere the parallax at the surface of which is about 0″.003, in which sphere, according to Newcomb's star density, there would be found over six million lucid stars.

ASTRONOMY IN THE HIGH SCHOOL. II.

MARY E. BYRD.

FOR POPULAR ASTRONOMY.

THE CONSTELLATIONS.

The practical study of elementary astronomy begins naturally with the constellations. Whether our girls and boys have only

one short term with the subject, whether they go on with several years' study, or whether they are to be the astronomical teachers and astronomers of the future, let us begin by introducing them first to the pleasure of the stars. The world beyond the horizon line should be opened up to them, the world that is still new in spite of centuries of exploration. There should be unstinted enjoyment for them in the royal progress of celestial bodies, in the rising of the Pleiades and the Hyades and in the stately march of all the goodly host that Orion leads. They will not know less that they enjoy more.

Viewed also from the coldest academic standpoint, the study of the constellations comes first. It is necessary for practical work of any kind that our students know how to see when they look up at the heavens. To recognize different degrees of brightness, to determine angular direction, to estimate the relative length of star-lines, to pass by careful steps from a known to an unknown object, these things are fundamental, and yet they are best and most quickly mastered not by direct effort, but by picking out and drawing the constellations. Nor is this training of eye and hand by any means the only advantage gained. Familiarity with the star groupings themselves is of vital interest to naked-eye observers. For then in a very real sense the stars are fixed. They constitute the practically unchanging background upon which are displayed all shifting celestial phenomena.

It was by means of the fixed star-pattern that ancient peoples gathered a surprising fund of knowledge about the solar system. Our students of today should follow in their foot steps, at least, for a little way. With the stars as reference points, they are to define the monthly course of the Moon, trace out long or short arcs of the paths in which the planets circle around the Sun, determine the direction of a bright comet's progress, and the length of its visible path, follow the flight of a meteor, and bound the zodiacal light. Without some acquaintance with the stars they cannot so much as know whether or not they are looking at a planet. Again and again at the coming of winter, otherwise intelligent people take Sirius for a planet.

Doubtless there are a score of good ways to teach the constellations. There are certainly a few poor ones. The different kinds of planispheres, illuminated star pictures and other like devices are, in the judgment of the writer, worse than useless. Even the celestial globe confuses rather than helps the average beginner. Any one who has studied geography and used a common atlas should begin at once with star maps which have the usual refer-

ence circles, with hours and degrees marked for right ascension and declination. It is not amiss to give a part of the first class-exercise to these maps, calling attention to points of likeness between them and geographical maps, noting how striking configurations are outlined and constellations bounded, and picking out the particular constellations to be identified on the first clear evening.

Since, with few exceptions, it puzzles beginners to recognize in the sky what is depicted on the map, some pains must be taken in giving explanations. The following is one of the common forms employed:

IDENTIFICATION OF THE BRIGHT STARS IN AQUILA.

1. Facing the arch of the Milky Way to the southwest and looking up a little more than half way to the zenith, you see right in the Milky Way a row of three bright stars, nearly equidistant, the brightest being in the middle. That one is α Aquilæ, called also Altair. The upper one of the three is γ and the lower β.

2. Prolong the star-line $\gamma\beta$ southward once and two-thirds its length and you find the fairly bright star θ.

3. From θ pass northward again to the Milky Way, and look to the right of α for the star δ, about as bright as θ, which with θ and α forms a fair isosceles triangle, θ being at the apex.

4. Through δ extend a line upward equal in length to $\gamma\theta$ and parallel to it. Near its extremity ζ is found.

5. Now if these stars have been correctly identified, $\gamma\theta\delta$ and ζ mark out quite a symmetrical parallelogram.

Time is saved in the end by going slowly at first, and patiently repeating directions. Even if it takes two or three evenings, it is well to wait till the class is familiar with ten or more constellations before requiring drawings. Any method or no method of mapping is practically satisfactory if the reproduction on paper fairly represents the configuration in the heavens. There are some advantages, perhaps, in using the card-patterns and construction lines suggested by the writer in a former article.* A card-pattern is simply a stiff piece of card board cut to fit the page of the observing book with two dots on one side for the stars that fix the reference line for the given constellation. Construction lines are best explained by a concrete example like the following:

CONSTRUCTION LINES FOR CASSIOPEIA.

$\alpha\beta$ = Reference line.

The stars $\alpha\beta\gamma\delta\epsilon\iota\kappa$ must be included.

* POPULAR ASTRONOMY, March, 1902.

Estimate $<\beta\alpha\gamma$.
Compare $\alpha\gamma$ with $\alpha\beta$. Put in γ.
Estimate $<\alpha\beta\kappa$.
" $<\gamma\kappa\beta$. Put in κ.
Prolong $\beta\gamma$ and estimate $\delta\gamma$ in terms of $\gamma\beta$. Put in δ.
Prolong $\alpha\gamma$ and place ϵ and ι with reference to a line parallel to $\alpha\gamma$, drawn through δ.

Write out.

Estimate of $<\beta\alpha\gamma$.
" " $<\gamma\kappa\beta$.
" $\delta\gamma$ in terms of $\gamma\beta$.
" $\iota\delta$ in $\delta\beta$.

Working from such directions as these, beginners are likely to escape the worry and delay of futile efforts in getting started, and to realize from the first that emphasis is placed on accuracy in estimating lines and angles rather than on pictorial effect. For the laboratory instructor who must criticise perhaps fifteen or twenty maps in an hour, it is certainly no small gain to have all those of one constellation drawn on the same scale, similarly placed on the page, and based on the same measurements.

The constellations included in different schemes of study will vary of course; but those in the zodiac have special claims to consideration, for through them runs the course of the Moon and bright planets. As regards the number to be required, it is far better to recognize easily, from the characteristic grouping of a few stars some thirty or more, no matter how they are placed with regard to the horizon, than to have a minute and detailed acquaintance with eight or ten. Exhaustive treatment is not necessary for thoroughness and accuracy, and while striving earnestly to attain the latter, we should not hold with too painful effort to scientific formality. There must be room for the opera-glass and the beauties it reveals in clusters and nebulæ. There must be time for the myths and legends that have gathered about the constellations since the childhood of the race. Knowledge that comes through the gateway of pleasure possesses vital force.

Smith College Observatory,
Northampton, Mass.

SOME DETAILS OF THE RECENT SOLAR CYCLE.

ROSE O'HALLORAN.

For Popular Astronomy.

To those who have made a continued study of the solar surface during the years just past, the large sun-spots of October were a

tardy though effective signal that the intermittent period when spots are few and faint had passed away. An unspotted photosphere will now be a rare spectacle to telescopic vision.

Ruling the motions of Earth and planets by the attraction of its enormous mass, redeeming them from perpetual gloom with its radiation, the potent center of the solar system is nevertheless itself dominated by an unknown force so effective and unfailing in its operations that scientific interest has been keenly aroused during the last half century. Observations dating from 1610 established the fact that a large area of the solar surface is profusely spot-strewn for a few consecutive years, a condition invariably followed by a gradual decrease, until even months may pass of umblemished photospheric whiteness. These alternate conditions, known as the sunspot maximum and minimum, form a cycle generally lasting about eleven years and from one to two tenths. Though the extremes are in marked contrast, the boundary between them is not sharply defined nor has it a permanently midway position, the minimum being frequently the more prolonged.

That the surface of a vaporous and intensely heated body, more than a million times the size of the Earth, should be in a state of tumultuous disturbance accords with the known laws of heat and gravitation; but when it was found that solar tempests announce their presence by a deep-hued stain, show a distinct preference for certain zones of the Sun, observe unexplained laws as to differing rates of speed across the disk and maintain a fairly punctual period of increase and decline, the cause of these peculiarities became one of the foremost of astronomical problems.

Among many diverse theories the following receive the most favorable consideration: The dark areas may be the result of a downpour of passing meteors; or, in the climax of colliding currents on the seething surface, vapors may be cast forth, and on descending again in a state of comparative coolness, seem dark by contrast; or, violent whirlpools may frequent the zones most suited for cyclonic formation, and by suction bring down volumes of cooler matter from above. None of these theories however, rccount for the various complexities noticeable, while the eleven year period seems the most insolvable of Sun mysteries. Several astronomers, notably M. Loewy, the present Director of the Paris Observatory, ascertained many years ago that the positions of the planets, especially Jupiter the largest and Mercury and Venus the nearest to the Sun, yielded some evidence of co-operation in the periodicity of solar disturbance. Modern recognition of tidal effects among the heavenly bodies gives renewed force to

this theory. That Jupiter's time of revolution, nearly twelve years, would chiefly sway the photospheric tide is what might be inferred in such a case; and though maxima do not always correspond with the perihelion distance of the ruling planct, this may be a required compromise with the conflicting attraction of lesser tide-raisers. If it be that the circling planets thus waken tempestuous tides on the vaporous luminary, then our Earth can claim an humble share in the sublime process of Sun painting.

Of late years, maxima and minima have been carefully studied in detail, as thus only can further enlightenment be obtained, and as every locality is more or less subject to cloudiness, the combined records of several telescopists are generally requisite for a complete cycle of observation.

The following brief account, based on solar studies with a four-inch Brashear refractor, contains some of the characteristics of the two-fold period just completed.

An interruption of some length in the record, due to a journey to observe the eclipse of 1900, having occurred during the sun-spot minimum, causes little material change in the outline.

According to a recent careful revision of sunspot data published by Professor Wolfer of France, the minimum preceding this just past was at its extreme stage of unspottedness during the first months of 1890, and as a corresponding stage did not occur until the summer of 1902, this solar cycle has been unusually prolonged. The last maximum showed its approach towards the end of 1891, continuing the three following years with little abatement, but though a slight renewal of disturbance was noticeable since September, 1902, it was only recently, twelve years later, that the corresponding stage of a returning maximum was clearly indicated.

My recorded observations were commenced on the first of November, 1891. The critical period in the career of an average spot being its first invasion of photospheric whiteness, one aim of these observations has been to note the number of times that this was seen to have occurred.

A disfigured area whether stained by one spot or by many is classed as one solar storm when the sprinkling does not extend beyond twenty-five degrees of the Sun's surface which being about the limit of the largest spots, gives some clue as to the probable range of a single disturbance. This method, though giving a far lower numerical result than if each section of a discoloration were counted, avoids including any spot more than once. From November the 1st, 1891, to the same date of the present year,

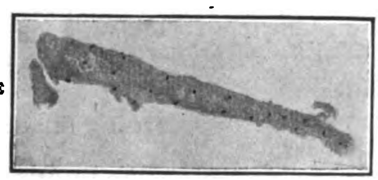
1903, the Sun was observed and the results recorded on 2,982 days, and according to the method adopted, 811 spotted areas were seen on the disk during that time. Two-thirds of the disturbances occurred within the first five years, the remainder being distributed over the ensuing years with decreasing frequency until September, 1902, when a slight but distinct increase of activity set in. During the maximum and minimum between 1879 and 1890, the spottedness of the surface south of the Sun's equator was more than double that of the northern zones, according to Comstock's text-book of astronomy; and from November, 1891, to this present November, 1903, solar storms have also been fewer in the northern hemisphere, but in the lesser disparity of seven to ten. Owing to misleading perspective effects at certain seasons, this estimate was deduced from 567 eruptions distinctly beyond equatorial zones, in which latter, accurate measurement of solar latitude is difficult. Of the entire number of spotted areas, namely 811, about forty sufficiently conspicuous to be visible under favorable circumstances without magnifying power may be classed as large; while solar tempests which from depth of hue combined with immense extent may be called giant spots stained the glowing orb to the distinct gaze of the world at large on four notable occasions. The first, one of the largest on record, measuring 150,000 miles in length and 75,000 in breadth, appeared inside the southeast limb on the 4th of February, 1892; the second assumed nearly equal dimensions when it ploughed the southern hemisphere in the beginning of August, 1893; the third with compact umbra and enormous penumbra tinged the southern zones in September, 1898, while the interesting formation of last October, the initial footprint of a returning maximum, lingered near the southerly border of the sunspot region from the 5th to the 17th of the month.

Terrestrial storms of air or ocean convey no adequate idea of the reality of these tumultuous battlefields of heat and motion on the vaporous Sun. To state that a spot cavity is ten times the diameter of the Earth, that our globe would be consumed to the centre if in contact for one minute with even the darkest umbra, and perhaps in the fury of contending currents might be ejected thousands of miles upward is but a restricted outline of the possibilities of solar agitation. Dwarfed by a distance of 93,000,000 of miles, monster discolorations of every shape have penned their stormy history again and again on the photospheric tablet, but as yet these hieroglyphics of the Sun have remained partly unread. The recent great sunspot, the largest in five years, reap-

peared in due time on the first of November and, though decreased in size, an additional outbreak in the rear rendered the group again visible to the naked eye as it crossed the disk. There

GREAT SUNSPOT OF 1903.
Oct. 11, 10h 30m A. M.

is good evidence that many of the larger spots were of long duration and came round to view more than once, but complete identification is difficult on account of change of form and position when on the unseen side of the rotating orb. Another feature of



A PENUMBRAL SPOT OF GREAT LENGTH.
1896 Sept. 14, 1h 20m P. M.

the cycle was the occasional disconnected stream of average eruptions from east to west revealing a wide distribution of activity. The most conspicuous case was in May, 1894, when three-fourths of the solar circumference was wreathed in spots from twenty to thirty degrees apart; but the lesser displays of streaminess thrice in 1895, once in 1896, and once in 1898, were also remarkable.

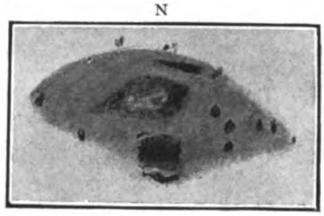
A specially interesting detail in a floating cavity of the photosphere is an indication that its dark depths form a whirlpool ac-

Jan. 14. Jan. 15. Jan. 19.
CYCLONIC SUNSPOT 1892.

cording to the theory of M. Faye, the French scientist. A cyclonic

tendency was noticed in several spots, the most remarkable being those of January 1892 and April 1899.

As early in the maximum years as August, 1894, an unspotted condition of the disk was again seen, the 25th of that month bringing a more unblemished surface to view than had appeared in two years and ten months. Thenceforth a spotless disk be-



GREAT SUNSPOT OF 1892.
Feb. 8 (Noon).

came more frequent, the culmination being eighty-six days distributed throughout 1901, and one hundred and forty-seven days throughout 1902. Of these latter, from June the 12th, to September the 11th, the surface was in a state of unusual quietude; occasional cloudy days however breaking the positive evidence that three months of continued inactivity had existed. From 1897 to 1901, zones not far from the Sun's equator were chiefly the scene of the diminishing disturbance, but within the last two years, higher latitudes resumed activity, which scattering of forces is frequently a pressage of returning maxima. The present renewal of a spotted condition is opportune. Though much information has been gained in the last fifty years some important points may need to be unlearned, as the marvelous properties of radium, and its incomprehensible relation to helium recently dis, covered by Sir William Ramsey, open possibilities as to solar heat-light and radiation unthought of heretofore.

THE STUDY OF THE VARIABLE STARS. X.
U CEPHEI—ITS LIGHT-VARIATIONS.

PAUL S. YENDELL.

FOR POPULAR ASTRONOMY.

The variations of U Cephei, and their type, were detected by Ceraski in 1880, and announced by him in the *Astronomische Nachrichten*, Vol. 97, col. 319. At that time only five stars of the Algol type were known, the last one previously discovered having been U Coronæ, found by Winnecke in 1869.

A discovery of the kind was much rarer at that time than it is now, and naturally excited much interest among those astronomers who occupied themselves with the variable stars. Many observers at once turned their attention to the new variable, and Glasenapp, Wilsing, Knott, Schmidt, Pickering, the Baxendells, senior and junior, and others, published numerous observations during the early years.

I took up the watch on the star in 1888, when the early close attention to it had somewhat relaxed; and since that time, no year has passed during which I have not made more or less observations of it, though one or two have gone by without my having recorded any observed minimum.

The main peculiarity of the light-curve was at once noticed, a peculiarity which it was the second star to exhibit, the first being S Cancri, but which is now so common as almost to constitute a sub-type by itself.

The work of the early observers, however, was for the most part directed to the investigation of its elements of variation, rather than to the course and character of its light-changes. Knott's numerous observations, extending from the time of the star's discovery until 1889, are mostly confined to the three hours on either side of the minimum, and very few of them were made during the time of ths star's normal brightness.

The earliest mean light-curve of U Cephei known to me is Pickering's, published in 1881, in the *Proceedings of the American Academy of Arts and Sciences*, Vol. XVI. It was baeed on about three hundred photometric observations made at the Harvard College Observatory. A discussion of the star's variations, including a mean light-curve, was published by Wilsing in 1884 (*Astronomische Nachrichten*, 2569). In 1889, Chandler (*Astronomical Journal*, Vol. IX, p. 49), published a discussion of the star's elements of variation, with "Spring" and "Autumn" mean curves, and a comparison of the same with those of Wilsing and Pickering, previously published.

Since the date of Chandler's paper, the only mean light-curve of our star that has come to my knowledge is that of Bohlin, reprinted from the *Nachrichten* in No. 93 of this publication.

Early iu the nineties I began to observe U Cephei for the definite purpose of accumulating a mass of material sufficient for the formation of a mean light-curve of a somewhat definitive character. My minimum limit was placed at a thousand observations, and my intention was to secure as many of the Spring as of the Autumn curve. Observations were made whenever convenient, not

limited to the determination of minima, and especial efforts were made to get as many as might be at the beginning and end of the light-changes, where the observations are usually difficult and scanty.

Mostly from conditions dependent on the weather, it was not found practicable to secure as many observations of the Spring curve as of the Autumn one, and at the close of the observations of 1902, of eleven hundred and seventy-five observations only two hundred and eighty-six belonged to the Spring curve.

I began the reductions for the mean curves in the early part of 1902. I had intended to use the Harvard Photometry scale of magnitudes, as being the only photometric measures available for stars of all the magnitudes included in the range of the variable. Measures of the comparison-stars used were kindly furnished for the purpose by Professor Pickering. But tue values of the stars *d* and *b* (see Table of Comparison-stars) in these measures were discordant with their relative values according to both my own light-scale, formed from twelve years' observations, and that of Knott; and after reducing a considerable number of observations I found that the form of the curve near the minimum would be seriously distorted from this cause. The use of the Harvard magnitudes was thereupon abandoned.

Very shortly after the reductions had been suspended for this reason, and when I had almost decided upon the use of my provisional magnitude-scale previously used, formed from my own light-scale, Dr. Muller, of the Potsdam Astrophysical Observatory, very kindly offered to make measures of these comparison-stars for the purpose of my work. This offer I gladly accepted, and in Angust 1902 he sent me his results. His measures proved quitė accordant with my light-scale, so that simple relations between them were readily established, and the work was resumed.

. The comparison-stars and light-scale used are as follows: The first column of the table shows the notation used; the second, headed DM, their Durchmusterung numbers; the third, P, their magnitudes according to the Potsdam measures; and the fourth, Lt., my own step-scale, formed from all my observations to 1900, July 4, and retained in these reductions because in my judgment the later observations would not have sensibly changed it.

	DM	P	Lt.
	°	m	St.
k =	81 13	6.58	31.9
e =	18	7.43	24.4
f =	30	8.04	19.3
g =	27	8.53	14.8
h =	29	8.57	14.0
a =	80 21	8.93	9.2
b =	22	9.17	4.9
d --	81 22	9.29	1.9
e =	80 23	9.44	0.0

By the above light-scale, the value of a step is $0^m.114$ from *k* to *g*, and $0^m.052$ from *g* to *c*, being nearly twice as great among the brighter stars as among the fainter ones, but pretty constant in each group.

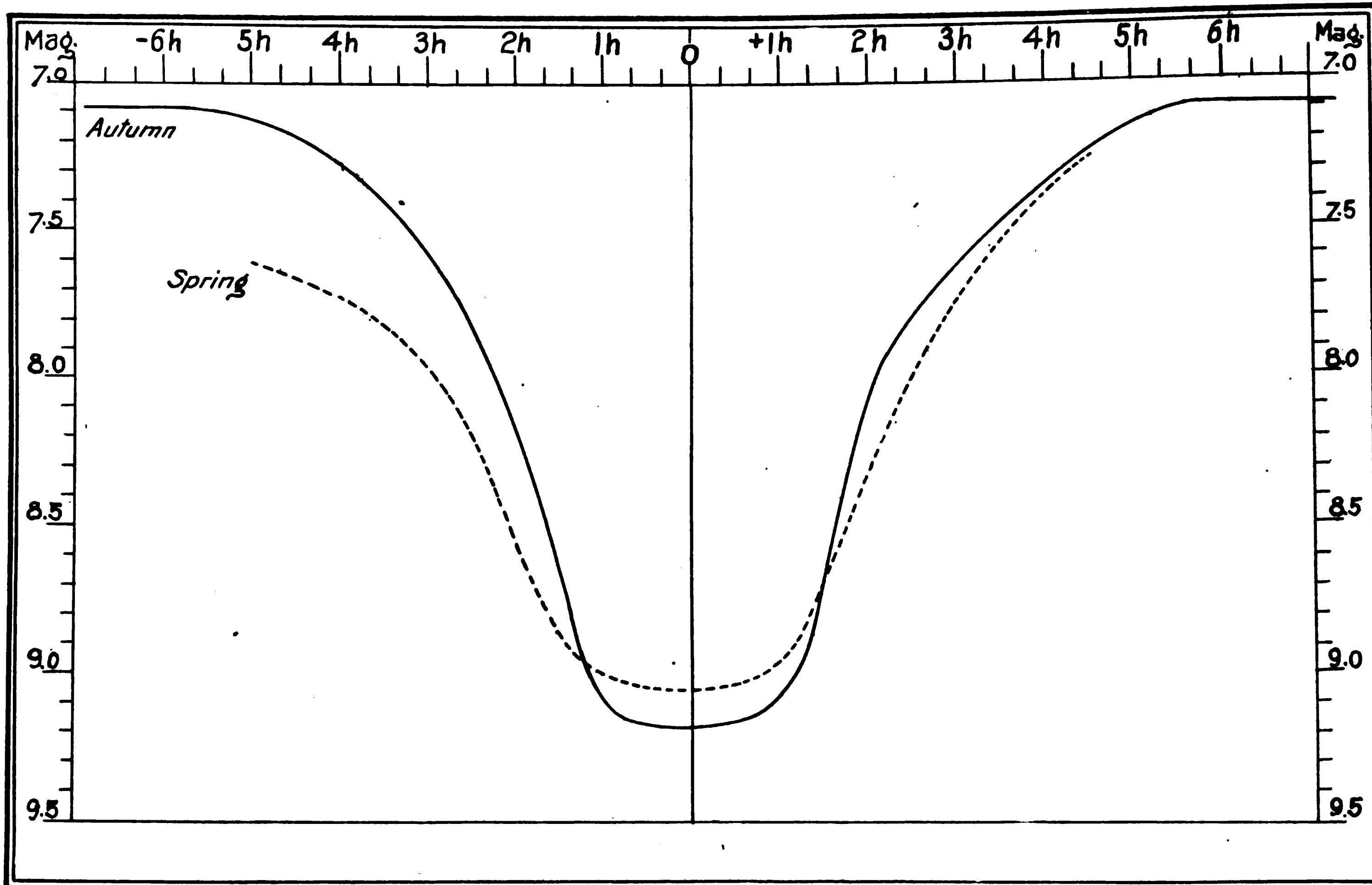
I am now fully convinced that the apparent difference between the "Spring" and "Autumn" curves of the star is purely subjective. Knott's separation of the minima into sets of odd and even epochs is contradicted by the fact that in Chandler's curves above alluded to, these groups are interchanged. Whereas Knott's even minima fell in the Spring, Chandler's, on account of the relative longitude of his place of observation, came in the Autumn, and *vice versa*. But Chandler's results for Spring and Autumn are respectively the same as Knott's. The former (*loc. cit.*) calls attention to the possible subjective nature of the phenomenon.

I have lately had occasion to reduce a number of series of observations of U Cephei made by different observers, ranging in time from the date of the discovery of variability down to the end of the year 1902, and find that in nearly all the series since Chandler's the minima observed in the Spring have been the odd, and in the Autumn the even epochs. In all these series except my own, the Spring minima are the fainter, by varying amounts. In my own series they are the brighter; but the difference steadily decreased as my precautions to avoid subjective errors became more and more sedulous, and as my experience with the star grew, until in the minima from 1898 to 1902 it almost wholly disappears. Besides, the asymmetry of the curve, reversed in the Spring and Autumn series of all the observers, almost entirely disappears in this group, especially in the much more fully observed Autumn curve.

The details of all the above facts may be found fully stated in my paper on the light-changes of U Cephei, published in the *Astronomical Journal*, No. 551.

The elements on which the present curves are based are provisional. They satisfy my observations at least as well as any yet proposed. The departure from Chandler's elements of 1897 began about 1894, and has gone on increasing until in the Autumn of 1902 the minima were nearly three hours late. (See also Hartwig's VJS Ephemerides, for 1902, p. 269, and 1903, p. 285).

It was necessary therefore, to find elements which would fairly represent the observed dates, and the following, suggested by Chandler in 1901, satisfy my observed minima, with an average residual of rather less than nine minutes.



MEAN LIGHT CURVES U CEPHEI.

Elements.

1880 June 23^d 7^h $43^m.5$, G. M. T., 2^d 11^h 49^m $44^s.7$ E.

As the difference between the two curves is undoubtedly subjective, and due to the varying presentation at different hour-angles of the group formed by the star and its comparison-stars, it seems that the dividing line between the two groups should be drawn at that angle at which these disturbances disappear. This occurs at hour angles 2^h 24^m West and 9^h 36^m East.

The line passing through these two hour-angles was accordingly adopted as the critical line, and all the observations made in hour-angles east of it were used in the formation of the East or Autumn curve, and those west of it for the Spring or West curve.

In forming the mean curves, seven hundred and eighty-one observations were found available for the East, or "Autumn" curve, and two hundred and sixty-eight for the West or "Spring" curve. At the normal light there were eighty-five observations in East hour-angle, and eighteen in West, one hundred and three in all; from these twenty-three normals were formed.

In forming the normals for the Autumn curve, as far as practicable twenty observations were used for each normal, so as to give them approximately equal weights; but at the beginning and end of the period of change, the observations were less numerous, and the normals therefore formed from smaller groups. The corresponding normals for the Spring curve were formed from ten observations each.

The following table presents the normals from which the curves were formed. The column T — *t* contains the interval from the computed time of minimum; M the magnitude; *o* the number of observations which make up the normal; and *v* the departure of each normal from the curve as drawn.

The last fifteen normals in the Autumn table, and the last eight in the Spring one fall in the time of the star's normal light. They give no indication of any real fluctuation in brightness during that part of the period, the average departure from a mean of $7^m.09$ being $0^m.03$, and the probable error of a single normal $0^m.02$. The residuals are pretty impartially distributed over the whole of this part of the star's period, and their signs show a fairly satisfactory alteration.

The mean minimum light shown is for the Autumn curve $9^m.18$, and for the Spring curve $9^m.06$. Neither curve shows any correction to the computed time of minimum.

AUTUMN.

T − t h	m	M	o	v	T − t h	m	M	o	v
− 4	55.8	7.14	10	+.01	+ 0	15.9	9.16	20	−.01
4	31.4	7.38	10	+.20	0	34.6	9.18	20	+.03
4	13.0	7.12	8	−.11	0	48.4	9.10	20	−.02
3	44.8	7.37	15	+.05	0	56.6	9.11	20	+.03
3	34.7	7.41	14	+.04	1	6.0	9.05	20	+.02
3	17.3	7.40	15	−.05	1	13.8	8.96	20	+.02
3	4.1	7.46	20	−.08	1	20.9	8.75	20	−.10
2	52.0	7.67	20	+.04	1	26.3	8.83	20	+.10
2	40.1	7.82	20	+.09	1	33.9	8.56	20	−.02
2	22.8	7.86	20	−.06	1	39.7	8.39	20	−.01
2	10.5	8.12	20	+.06	1	47.9	8.33	20	+.09
1	59.8	8.11	20	−.08	1	56.6	8.08	20	−.02
1	51.6	8.43	20	+.12	2	4.6	7.97	20	−.02
1	44.2	8.41	20	.00	2	21.2	7,81	20	−.03
1	37.5	8.55	20	+.02	2	48.8	7.69	20	.00
1	30.7	8.56	20	−.08	3	31.8	7.48	19	.00
1	21.8	8.84	20	+.02	4	56.3	7.13	4	−.03
1	16.2	8.87	20	−.07	5	44.5	7.11	6	+.02
1	8.3	9.06	20	+.04	7	9	7.09	3	.00
1	1.2	9.08	20	−.01	9	18.5	7.10	4	+.01
0	52.9	9.14	20	+.01	13	58.1	7.09	6	.00
0	41.0	9.16	20	.00	16	26.8	7.05	5	−.04
0	28.1	9.16	20	−.01	20	16.2	7.09	5	.00
− 0	16.9	9.23	20	+.06	21	35.6	7.09	9	.00
+ 0	8.1	9.17	20	−.01	25	11.7	7.12	10	+.03
27	44.5	7.14	6	+.05	46	6.1	7.10	4	+.01
29	26.1	7.10	6	+.01	49	17.8	7.98	11	−.01
32	34.8	7.06	4	−.03	52	27	7.03	3	−.06
+ 42	18.3	7.07	6	−.02	+ 54	11.3	7.05	3	−.04

SPRING.

T − t h	m	M	o	v	T − t h	m	M	o	v
− 4	52.1	7.62	10	.00	− 0	1.6	9.05	10	−.01
3	45.3	7.77	10	+.01	+ 0	16.1	9.03	10	−.03
3	18.5	8.24	10	+.38	0	36.1	9.04	10	−.02
2	36.0	8.09	10	−.03	1	11.8	8.81	10	−.10
2	30.6	8.10	10	−.10	1	28.0	8.65	10	−.05
2	20.2	8.35	10	+.04	1	49.7	8.48	10	+.05
1	59.7	8.56	10	.00	2	8.4	8.29	10	+.07
1	47.4	8.64	10	+.08	2	27.7	7.96	10	−.05
1	42.1	8.74	10	−.03	2	49.8	7.82	7	+.01
1	31.7	8.81	10	−.05	4	34.3	7.28	2	.00
1	23.9	8.84	10	−.04	8	3	7.06	2	−.03
1	14.9	8.96	10	+.01	19	13	7.11	2	+.02
1	5.3	8.95	10	−.04	20	31	7.11	2	+.02
0	57.0	9.03	10	+.02	31	13	7.07	3	−.02
0	49.4	8.99	10	−.04	33	15	7.08	3	−.01
0	43.7	9.06	10	+.02	44	23.5	7.06	2	−.03
0	26.4	9.07	10	+.02	46	27	7.11	2	+.02
− 0	9.8	9.09	10	+.03	+ 47	26	6.96	1	−.13

According to these curves, the duration of the star's light-variation is longer than it has hitherto been stated. It is from $-5^h 40^m$ to $5^h 40^m$, and therefore occupies $33^h 20^m$. These limits are well-defined in the Autumn curve, but the beginning of the Spring curve is much less satisfactory. From some unknown cause, doubtless subjective, it is much distorted to about $-2^h 30^m$.

The readings from these curves are as follows:

	Autumn			Spring		
T − *t*	Before M	After M		Before M	After M	T − *t*
h m						h m
—5 40	7.09	7.09				
20	7.10	7.11				
5 0	7.12	7.15		7.60		5 0
4 40	7.16	7.21		7.64		4 40
4 20	7.21	7.29		7.67	7.30	4 20
4 0	7.27	7.37		7.72	7.39	4 0
3 40	7.34	7.45		7.78	7.49	3 40
3 20	7.44	7.54		7.86	7.61	3 20
3 0	7.57	7.64		7.97	7.74	3 0
2 40	7.73	7.73		8.10	7.90	2 40
2 20	7.95	7.85		8.31	8.10	2 20
2 0	8.19	8.05		8.56	8.32	2 0
1 40	8.49	8.40		8.78	8.56	1 40
1 20	8.84	8.85		8.93	8.80	1 20
1 0	9.10	9.07		9.00	8.97	1 0
0 40	9.17	9.14		9.04	9.02	0 40
0 20	9.17	9.17		9.06	9.04	0 20
0 0	9.18	9.18	Minimum.	9.06	9.06	0 0

With this exception, the differences between the two curves are: the comparative flatness of the Spring curve, its brighter minimum, and its asymmetry as compared with the Autumn curve.

The latter is so far the more fully observed and better made out curve, made from observations taken at far the more favorable season of the year, and the precautions to avoid subjective errors have been so unremitting, that it seems to me to be probably a very good approximation to the star's real light-curve. Its departures from actual symmetry are very slight in the best determined part, up to $7^m.5$, and at $9^m.08$, $8^m.65$, and $7^m.73$ they disappear altogether.

If we form a symmetrical curve from the means of each pair of ten-minute readings, the probable error of one of these readings is $0^m.025$, while their mean departure from the symmetrized curve is $0^m.027$,

Assuming that the minimum light is constant from $-1h$ to $+1h$, the probable error of one of the nine normals is $0^m.018$, while their mean departure from their mean value is, as in the other part of the curve, $0^m.027$. So that the indications are very strong, that these assumptions are good approximations to the actual state of things, although numerically they fall short of actual proof.

After fifteen years' constant and careful observation of U Cephei, the impression remaining on my mind is, that the course of the star's light-changes is that which would result from an annular eclipse; a symmetrical light-curve with inflection increasing with its proximity to the minimum, and an interval of constant minimum light.

Dorchester, 1903, Dec. 12.

THE MARKINGS AND ROTATION PERIOD OF SATURN.

W. F. DENNING, F. R. A. S.

The conspicuous markings observed in the northern hemisphere of Saturn during the present opposition have greatly encouraged observation of, and interest in, a beautiful object. The complaint has sometimes been made that this planet, though forming an unique picture, attractive in the highest degree, yet lacks variety and the evidence of similarly great and abundant changes which render the study of Jupiter so entertaining. But the aspect of Saturn during the past summer has led to a modification of opinion on this point, and has proved that "the ringed orb" is occasionally the scene of extensive disturbances, and that the vapors surrounding him are travelling in parallel currents, differing in their relative velocities even more widely than those on the surface of Jupiter. In future years it is fair to assume, therefore, that Saturn will be more closely studied than hitberto. Apparently he has been somewhat neglected in the past; his ring-system has usually occupied chief notice, and perhaps diverted attention from more important phenomena displayed on the ball. In viewing this planet the observer's principal aim has been to obtain glimpses of the crape ring, Encke's division in the outer ring, or certain of the satellites, and thus the configuration in detail of the globe has escaped critical survey.

Astronomical records furnish comparatively few instances of irregular markings on Saturn, and when objects of this kind have been detected they do not appear to have always been followed with the necessary persistency. Sir W. Herschel was the first to discover evidences of rotation, and to determine a value for it. He narrowly watched certain inequalities in a quintuple belt, visible in the planet's southern hemisphere in 1793, December, and 1794, January, and wrote in the *Philosophical Transactions* for the latter year, "I can at present announce the reality of the quick rotation by means of 154 revolutions of the planet," and "We may conclude that the period is exact to $\pm$ 2 min., and we need not hesitate to fix the rotation of Saturn upon its axis as $10^h\ 16^m\ 0^s.44$."

Schroeter*, of Lilienthal, made many observations of this planet more than a century ago, and derived rotation periods of $11^h\ 40^m\ 30^s$, $11^h\ 51^m$, and rather more than 12^h, from various markings he followed, but these results are very doubtful, and astronomers have never attached any weight to them.

Schwabe, of Dessau, observed markings in 1847, and a round bright spot near the S. limb was noticed by Busch and Luther in 1848. Certain dark patches were seen by Bond in 1848 and 1854, and re-observed by De la Rue in 1856. Lassell, Jacob, Coolidge, Dawes, Secchi and a few others also detected spots at about the same period.

Lassell wrote in 1857, January 8: "There are certainly chronic changes of great magnitude occasionally occurring on the face of this planet."

Dawes stated* in 1858, January: "I have observed a well-marked light spot in the S. hemisphere of Saturn which I estimated to be at about 40° or 50° of S. latitude. It was nearly in the axial line on January 11, at 10^h 30^m G. M. T., and again on January 14, 11^h 20^m, on both occasions a little past it."

Lassell viewed Saturn with a magnificently defined image in his 20-feet reflector of 20 inches aperture, powers 430 and 650, on 1858, April 17, just before 9 P. M., and said,† "Near the preceding limb, and a little south of the equatorial dark belt, was a brighter portion, too large to be called a spot yet sufficiently defined or marked out to be useful in determining the rotation of the planet."

The white spot seen by Dawes on 1858, January 11 and 14, and that observed by Lassell on April 17 of the same year, were probably identical objects, with a rotation period of nearly 10^h 25^m. Dawes' two observations sufficiently prove that the marking exhibited a rate not differing greatly from 10^h $24\frac{1}{3}^m$.

Professor Asaph Hall attentively studied Saturn during the fourteen years from 1875 to 1889 with the great Washington refractor of 26 inches aperture by Alvan Clark, and found that the ball of the planet presented very few changes, the most remarkable being the outbreak of an equatorial white spot, first seen on 1876, December 7. Professor Hall said that "on poor nights when the image is blazing and unsteady we can see and can imagine many strange things about this wonderful object." The white spot was watched from 1876, December 7, to 1877, January 2, by Professors Hall and Eastman at Washington, by Mr. A. G. Clark at Cambridgeport, and was also seen by several other American observers. A number of transits were secured, and from these it appeared that at intervals of three days the spot arrived at the planet's central meridian 16 minutes earlier than before. Profes-

* *Monthly Notices*, XVIII., p. 72.

† *Ibid*, XVIII., p. 231.

sor Hall found for the time of rotation $10^h\ 14^m\ 23^s.8$, with a probable error of only 2.3 secs.*

In 1891 and three following years a considerable number of bright and dark spots near the equator and in certain other latitudes of Saturn were discerned by Mr. A. S. Williams, of Brighton, with a 6½-inch reflector. The results were discussed and summarized in *Monthly Notices*, LIV., p. 298–314, and LV., p. 354–67.† The rates of the various objects differed slightly, ranging between about $10^h\ 13^m$ and $10^h\ 16^s$, but they appeared to present a satisfactory agreement with the earlier values of Herschel and Hall. It is only fair to mention, however, that several other experienced observers‡ employing powerful telescopes quite failed to see any spots on Saturn at about the same period. It is not, however, our intention to discuss the question whether planetary markings can be easily seen in a 6½-inch telescope, and their individual forms traced while instruments of 36 inches and less fail to show any vestige of such objects. The remarkable efficacy of small telescopes in revealing planetary detail has often been admitted, but comparisons at the observatories of Mount Hamilton, Princeton, Chicago, and elsewhere have proved the undoubted superiority of large instruments.

In 1896 and 1897, M. Antoniadi, using the 9¾-inch refractor of the Juvisy Observatory, observed dusky condensations on the north equatorial belt, and from these he ascertained the rotation period as a little more than $10^h\ 14^m$.

During the last quarter of a century Professor Hall's determination has been regarded as a standard value for the rotation of Saturn. True, it was based on few observations extending over twenty-seven nights only, and upon an object obviously variable, for while at first it was round and 2 or 3 seconds of arc in diameter, it resolved itself at last into a bright streak.

The planet has been traversing the southern signs of Scorpio and Capricornus during the last few years, and its low position in the sky has had the usual effect in impairing the definition so much that observers in northern latitudes have not been successful in detecting any irregular markings on the disc. The present opposition has, however, provided developments of very important and interesting character. Professor Barnard was examining

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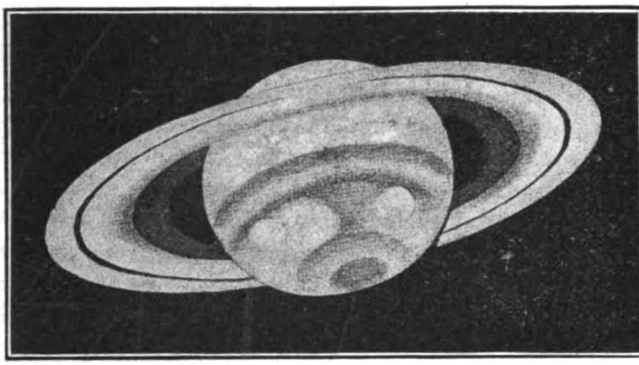
* *Astronomische Nachrichten*, No. 2146.

† See also *Ast. Nach.*, No. 3051.

‡ Professor Barnard, writing in 1903, June, says that during all the observations he had previously made of Saturn he had never seen any marking that could be used for determining the rotation period.

Saturn on June 15, 21^h, G. M. T., with the 40-inch Yerkes refractor, when he discovered a decidedly marked white spot halfway between the central meridian of the planet and the following limb. Clouds came over, but the marking was recovered on June 23rd, when its passage across the central meridian occurred at 21^h 42^m, G. M. T. It was seen again on June 24th, and the central transit observed at 18^h 58^m, G. M. T. On July 1st the writer, at Bristol (unaware of previous observations), noticed a bright spot on Saturn which must have been central at about



SATURN, 1903, AUGUST 21, 11^h.

14^h 1^m, though it had passed to some distance west of the central meridian when first seen. This object was subsequently assumed to be identical with Barnard's spot of June 23rd, for eighteen rotations of 10^h $14\frac{1}{2}^m$ would accord well with the interval elapsed between the pair of transits, but further observations disclosed the surprising fact that the new markings were moving far too slowly to be consistent with the usually accepted rate of Saturn's rotation. Graff, of Hamburg, pointed out in *Ast. Nach.* that the period of Barnard's spot, deduced from a few of the earlier observations, was about 10^h $39^m.01$, while Solà, of Barcelona, from more materials, found the value 10^h $38^m.4$. There have been several spots visible, both light and dark, and the chief one, first seen at the middle of June, has been watched at Bristol during the past five months, and its mean rotation period has been as nearly as possible 10^h 38^m. There is indication that the motion of this particular object has been slightly accelerated, but the evidence is not conclusive on the point. The other markings distributed along the same latitude show slight differences of period, and at the end of September they had become difficult objects.

In June the principal spot was large, and very much brighter than the light north-temperate zone in which it was placed. The

usual observational discordances have become apparent as regards the transit times, the form, dimensions, and aspect of the marking. Barnard on June 23 found the length, E. and W., $2''.6$. H. C. Wilson, at Northfield, Minn., on July 1 measured the length, $3''.93$, and width, $2''.36$, while Graff on June 26 gave the proportions $5''$ by $3''$. The spot is both followed and preceded by dusky patches stretching from the north equatorial belt to the polar shading. As seen by Wilson on July 1 it appeared surrounded by a narrow dark line, but the observer suggests that this may have been the effects of contrast. The north latitude of the spot, according to a measure by Barnard on June 23, was $36^\circ.4$, while Wilson determined it on July 1 as $31^\circ.1$.

Present indications are that the disturbance has, in its main features, practically subsided. Its lessons cannot fail to be of considerable interest. It has afforded the clearest proofs of a north-temperate current rotating 23½ minutes slower than the equatorial current as determined by Professor Hall from his spot of 1876-7. A comparison of the relative velocities leads us to the following curious deductions. The equatorial spots are moving so much faster than the north-temperate spots that they gain some 800 miles per hour upon them, and complete a circuit of Saturn relatively to their positions in about 12 days. A terrestrial hurricane is supposed to have an extreme velocity of about 100 miles per hour, but the wind currents on Saturn appear to be incomparably swifter. And the rapid equatorial drift on Saturn is probably persistent within small limits of variation like the equatorial current of Jupiter, which, during the last 25 years, has only varied between $9^h\ 50^m$ and $9^h\ 50\frac{1}{2}^m$.

On the latter planet the ordinary north-temperate spots rotate in $9^h\ 55^m\ 54^s$, which is about 5½ minutes slower than the equatorial spots. Both on Jupiter and Saturn, therefore, the mobile vapors on or near the equator are streaming along with abnormal velocity, outstripping other markings to N. and S., and also, probably, the actual rotatory movement of the immense spheres below. There may be occasional exceptions, it is true, as, for instance, the very rapidly moving dark spots which temporarily marked the north-temperate region of Jupiter in 1880 and 1891.

The closer scrutiny of Saturn in future years is desirable, and it seems well assured from the interest awakened by the prominent signs of activity recently displayed on the planet's surface. The investigation is a promising one. It may appear curious, on reflection, that comparatively little has been already accomplished in elucidating the visible surface phenomena of this wonderful orb,

forming as he does the most charming picture in the sky. Perhaps Saturn has sometimes been regarded as an object more suitable for exhibition than for sedulous research. In any case it is to be hoped that he will now receive more fitting recognition, for his belts and occasional spots merit as much attention as the variegated scenery of Jupiter or the wonderful and complicated canaliform aspect of Mars.

Previous observations suggest that the rotation of the equator of Saturn is $10^h\ 14\frac{1}{2}^m$, of the south-temperate region $10^h\ 25^m$, and of the north-temperate region $10^h\ 38^m$. But the materials are altogether too scanty for safe deductions. Many new observations are required of well-marked equatorial and south-temperate spots. We may have to wait years for the apparition of these, for Saturn's aspect is often serene and smooth, without any obvious irregularities in the belts and zones.

Postscript, Nov. 15.—Including my latest observations here with a 10-inch reflector, powers 312 and 332, the mean rotation periods of three of the best observed spots on Saturn work out as follows:

Object.	Interval of Observations. Days.	Rotations.	Period. h	m	s
Barnard's White Spot	138	310	10	37	52.4
White Spot	132	295	10	37	42.0
Dark Spot	120	270	10	37	56.4

The period appears therefore to be a little less than $10^h\ 38^m$, and bears out the suggestion previously made that the velocity has been accelerated.—From *Knowledge*, December, 1903.

IMPORTANT ASTRONOMICAL WORK IN PROGRESS.

W. W. PAYNE.

A brief look over the wide field of astronomical activity in all the different parts of the world shows that its devotees are busy workers, and that the great problems which they are trying to solve are neither few nor commonplace; but that they involve results that will probably be far reaching in utility and consequence for science in general and astronomy in particular.

The most important piece of work which has claimed the attention of more than a dozen observatories in different countries for the past few years, is the Photographic Chart of the Heavens. The photographic part of the work has been completed, and the meridian observations of reference stars is now in progress. Next comes the preparation of all this mass of matter for publication. Astronomers generally will be interested to know how well this

part of the great task will be done. It will be of large consequence to astronomy if the publication is worked out completely, and put into some orderly form, easy of reference, compact, inexpensive and without unnecessary details. There are some large observatories that will want this work to be made just as complete as possible, and probably such will not be satisfied with anything less than all that the voluminous records contain. Observatories generally, however, will probably prefer an edition of results for working uses that may possibly be less expensive yet very useful and within the reach of many astronomers.

Eros and the solar parallax is another of the pending problems of astronomy that has engaged the attention of more astronomers during the last two years than any other. There are two or three things in this work that are especially noteworthy. One is the trial of photography for the first time in the study of one of the most difficult problems known to astronomy. The plan has been to photograph the planet Eros while passing near the Earth, as often as possible, to obtain its apparent position among the stars very closely, to compare the same with the apparent positions of the planet obtained in like manner by other observatories in Europe; and by this means to obtain the parallax of Eros. This being correctly known the astronomer is enabled to obtain the parallax of the Sun, the unit of measurement for most distances in the solar system.

Some astronomers have used the equatorial telescope with the micrometer attached to find the place of Eros while passing stars well suited for the purpose of such measurements. This is a certain method of work, if a competent astronomer does it, and he can get enough such measures to ensure the accuracy of the results he is trying to get.

It is to be hoped that these two kinds of work on the parallax of Eros will be, each, so fully and faithfully tried, that the usefulness of photography for this kind of record may have a satisfactory and a crucial test. In order that the test may satisfy the most exacting astronomer that will scrutinize the work when it appears in contrast, these two kinds of work ought to have been performed by the same astronomer; for the personal equation under such circumstances might be an uncertain quantity. When it is remembered that the whole purpose of this Eros campaign is to lessen by some certain amount the error of the Sun's parallax which is now only about two one-hundredths of a second of arc, any one can see that only the best work of the most skillful will be of any use for an increase of our present knowledge of the Earth's distance from the Sun.

During this last year astronomers have been engaged very generally in measuring and reducing the photographic plates, and this work now seems to be nearing completion. We may expect soon to receive the results of those that have been in the lead of this work, and later that which is more definitive in kind and extent.

The radial motion of stars is another interesting theme for present astronomical research. The great observatories with instruments peculiarly adapted to this kind of observation have been busy at it, as results recently published plainly show. Potsdam, Yerkes and Lick Observatories have been deservedly prominent in this line of work.

The variable stars are claiming their full share of attention at the hands of experienced observers in this country, as well as elsewhere, and, one of the promising things about this comparatively new line of work is the fact that it has interested and continuously employed so many amateurs in recent years, that a goodly number of able observers have come to the front, and many of them are doing very creditable work.

The new line of observation in regard to variables is that pertaining to star clusters. Professor S. I. Bailey of the Arequipa Station of Harvard College Observatory was the first to call attention to this interesting field of study. He found 132 variables in Messier 3 in Canes Vanatici, 113 in cluster 5273 of the New General Catalogue of Nebulæ, 85 in Messier 5, out of 750 stars, and 122 in the great cluster ω Centauri. These are a few illustrations of the work in this direction which is only fairly begun. There is a considerable list of suspected variables that are now under observation which are not yet classed as known variables, because work on them has not yet gone sufficiently far. Some of the more prominent of these stars are, (according to J. E. Gore, in his new book entitled, The Stellar Heavens):*

δ Ursæ Majoris, which is the faintest star of the well-known seven, and has long been suspected of a variation of light; α Hydræ, a reddish star, which the ancient Chinese named "the Red Bird," and which the Arabians called the solitary one, beeause of its isolated position south of the "Sickle" in Leo. By the Harvard measures its magnitude is rated 2.02; λ Draconis is another which Mr. Gore himself observed from 1876 to 1891 during which time he noted variations in brightness to the extent of nearly a whole magnitude. "It was rated a third to fourth magnitude by Ptolemy, Al Sufi, Argelander and Heis, but Houzeau

* See notice of this book elsewhere in this number.

made it 4.5 in 1875. This star is of an orange hue, ond the spectrum of the third type." A few others are named because some amateur observers may not know of them, and because they are good objects for study by this class of observers.

α Serpentis	γ Geminorum
ε Pegasi	α Ophiuchi
83 Ursæ Majoris	α Sagittarii
ζ Piscis Australis	β Leonis
η Crateris	ζ Ursæ Majoris
α Eridani	γ Virginis

o Persei

Speaking about variables in general Mr. Gore says that it is a remarkable fact that such stars, except in a few cases, so far as known show any parallax or proper motion, which probably means that they lie, in space, at very great distances from the Earth.

For the last few years, one of the most perplexing themes in the study of meteoric streams has been the behavior of the Leonid showers. The leading authority in this branch of astronomy in the world at the present time is undoubtedly W. F. Denning of Bristol, England. His observational work and writings respecting every important feature of many meteoric streams are eagerly sought by all observers in America and very much used for guidance and instruction. As a means of setting before our readers some interesting points in the last November display of the Leonid Shower, we give below his report of it, as published in December *Observatory*, p. 458:

"Those who, notwithstanding the disappointments of previous years, stood out watching the sky on November 15 were amply rewarded by seeing a really fine display of shooting-stars. The Leonid radiant rose at about $10^h\ 15^m$, and soon afterwards occasional meteors of the usual aspect were directed from it. At midnight one meteor in every four or five minutes shot from the "Sickle." The display therefore had become well defined and fairly rich, but during the next two hours there was no great rise in the rate of apparition. Between 14^h and 16^h, however, the number rapidly increased, and an observer in a good open situation could enumerate about one meteor per minute. The next two hours afforded a further development, and between 17^h and 18^h the horary rate was variously estimated by different observers as from 120 to 250. My position at Bristol was not a good one, buildings and trees partially obstructing the view, but I counted 42 Leonids in the quarter of an hour from $17^h\ 30^m$ to $17^h\ 45^m$, and 15 Leonids in the five minutes 18^h to $18^h\ 5^m$, after which the display exhibited a perceptible decline in the increasing twilight.

Nearly all the meteors left streaks, and they were generally bright, quite a large proportion being equal to 1st magnitude stars. Some of them were equal to Jupiter, and occasionally one would rival if not exceed Venus. The latter rose at 14^h 45^m followed by the waning crescent of the Moon at $15^h 47^m$, and the two objects formed a very attractive picture.

During minor displays of the Leonids, I have usually found the radiant a sharply defined position, but this was not the case on the occasion of the recent display. Some of the Leonids with foreshortened flights in or near the "Sickle" distinctly showed that no contracted focus would include their various directions. It was necessary, in fact, to adopt a radiant-area of about 6° or 7° in diameter, near the stars ζ and γ Leonis, and around the point 151° + 22° as a center.

During the night I saw traces of minor showers near μ Andromedæ, α Aurigæ, α-β Persei, ζ and κ Draconis, and α Leonis Minoris, but they were very feeble and scarcely determinable amid the swarm of Leonids. I should be very glad to receive duplicate observations of an exceedingly slow ζ Draconid recorded here on November 15 15^h 41^m, and of a very long-pathed, slow-moving meteor from a radiant-point low in the southern sky. The latter object appeared on November 15, 15^h 59^m, and occupied five seconds in sailing along an arc of 45° from β Leonis to β Boötis.

The really rich phase of the Leonid shower must have been very short-lived. On November 14, 17^h to 17^h 45^m, in a beautifully clear sky, I did not see a single Leonid, though there were five other meteors. On the night following November 16 I looked out at times when the firmament was sufficiently clear, but few meteors appeared, and the Leonid radiant gave very slight traces of continued action."

By looking over the pages of this number of our magazine and the next, as a whole, it will be interesting to the thoughtful reader to notice how much space is given to topics relating to the Sun and to the Moon, either in the form of books, articles or paragraph news. The work of making and printing large photograph atlases of the Moon during the last two years has gone forward at a remarkable pace. The work of the Paris Observatory, as already previously noticed, at length, in these pages, has taken the lead in this particular. But, just now comes to our table the large and splendidly printed volume, in quarto form, on the same theme, by Professor W. H. Pickering, the result of his recent expedition to Jamaica mainly for this purpose. This book has a fuller notice elsewhere in this issue.

One of the chief objects of this painstaking photograph work of the lunar surface seems to be a desire, on the part of astronomers, to make a full and careful record of it now for the sake of future comparisons. The former methods of such study consisted in elaborate drawings to the minutest detail often on a very large scale for the sake of making a historical record. But such a method necessarily involved the personal equation of the artist astronomer who had undertaken the task, and the result of that has been to cause an almost endless discussion of the merits and the accuracy of the very best lunar maps that were ever made in this way. The question now is will photography remedy or help to correct this troublesome defect in our knowledge on the subject of changes that may or may not be going on respecting the surface of the Moon. As far as we can see at present, the prospect does not seem to be very encouraging. There are advantages in photography for lunar study, especially the aid secured by it in making a general map of the Moon: but when we come to the task of showing minute details on a large scale, the photographic work so far is rather disappointing. Practical observers know that the trained eye, at the telescope, takes advantage of the fine conditions of seeing for scrutinizing details that no skill can draw, nor any photographic plate catch and hold for successful development. The future may give aid by furnishing more rapid plates, or, improved methods of development so that it may be possible both to differentiate and then to integrate the details of the entire surface of a quick or slow photographic plate, so as to make it reveal to the astronomer the truth, the whole truth and nothing but the truth of its witnessing power. We still work in the hope of realizing this grand possibility.

Astronomical Phenomena During 1904.

Eclipses.

There will be two eclipses of the Sun and none of the Moon. Neither of the solar eclipses will be of any astronomical importance the one being an annular eclipse and the other a total eclipse, the path of totality lying wholly over water. The following data are taken from the *American Ephemeris* for 1904:

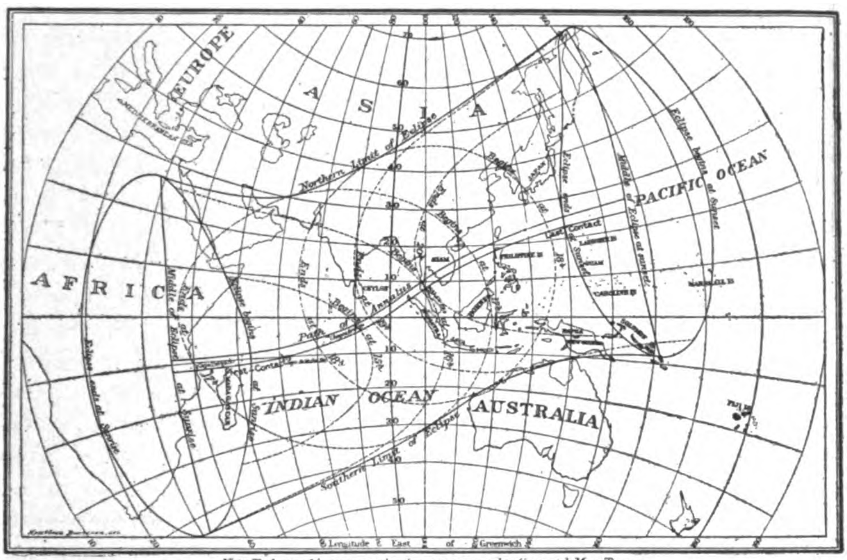
1. *An Annular Eclipse of the Sun*, 1904 March 16. The path of the annulus passes from the coast of Africa, just north of Madagascar, across the Indian Ocean, the Malay Peninsula and Siam, and ends in the Pacific Ocean southeast of Japan. As a partial eclipse it will be visible in the eastern part of Africa, the southern and eastern parts of Asia and on many of the islands of the Pacific Ocean.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, March 16, $17^h 45^m 39^s.1$.

Sun and Moon's R. A.	$23^h 46^m 8^s.07$	Hourly motions $9^s.14$ and $1^m 54^s.49$	
Sun's Declination	$-1^\circ 30' 8''.6$	Hourly motion	$+ 0' 59''.3$
Moon's Declination	$-1\ 12\ 46\ .6$	Hourly motion	$+ 9\ 21\ .4$
Sun's equa. hor. parallax	8 .8	Sun's true semidiam.	16 4 .1
Moon's equa. hor. parallax	54 24 .6	Moon's true semidiam.	14 49 .6

ANNULAR ECLIPSE OF MARCH 16th 1904



Note: The hours of beginning and ending are expressed in Greenwich Mean Time.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.	Longitude from Greenwich.	Latitude.
Eclipse begins	March 16 14^h $36^m.5$	52° 41′.7 E.	12° 58′.7 S.
Central eclipse begins	16 15 44 .0	35 53 .6 E.	10 15 .3 S.
Central eclipse at noon	16 17 45 .7	95 44 .8 E.	6 20 .6 N.
Central eclipse ends	16 19 37 .6	157 3 .7 E.	25 12 .4 N.
Eclipse ends	16 20 45 .0	140 17 .4 E.	22 29 .7 N.

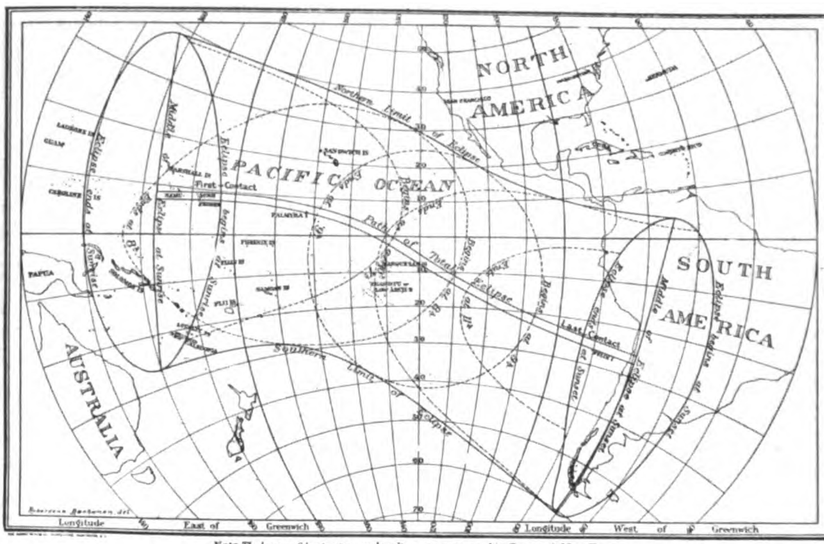
2. *A Total Eclipse of the Sun*, 1904, Sept. 9. The path of totality begins in the Pacific Ocean among the Marshall Islands and runs southeastward over the ocean, ending near the eastern boundary of Chili. In Chili the Sun will be just setting at the time of totality and the only other land touched by the umbra of the Moon's shadow is a few of the small islands of the Pacific. None of these islands is favorably situated for observing the eclipse, which is unfortunate, since the duration of totality of this eclipse is relatively long, amounting to 6^m 23^s at the maximum. This will be the opportunity of the astronomer, if there be one, who has at his command a private yacht, to locate himself in the path of the eclipse and observe the phenomena, unhampered by the necessity of attending to numerous instruments as in the ordinary eclipse. The longest duration of totality is a little south of the equator northeast of the Marquesas Islands.

Elements of the Eclipse.

Greenwich Mean Time of conjunction in right ascension, Sept. 9, $8^h\ 49^m\ 34^s.1$.

Sun and Moon's R. A.	$11^h\ 11^m\ 5^s.39$	Hourly motions	$9^s.00$ and $146^s.16$
Sun's declination	$+5°\ 14'\ 56''.3$	Hourly motion	$0'\ 56''.7$ S.
Moon's declination	$+5\ \ 4\ \ 30\ .7$	Hourly motion	11 32 .3 S.
Sun's equa. hor. parallax	8 .7	Sun's true semidiam.	15 53 .2
Moon's equa. hor. parallax	61 23 .0	Moon's true semidiam.	16 43 .6

TOTAL ECLIPSE OF SEPTEMBER 9TH 1904



Note. *The hours of beginning and ending are expressed in Greenwich Mean Time.*

Circumstances of the Eclipse.

	Greenwich Mean Time.			Longitude from Greenwich.		Latitude.	
Eclipse begins	September 9	6^h	$7^m.8$	176°	19'.0 E.	11°	9'.3 N.
Central eclipse begins	9	7	3 .0	162	49 .7 E.	7	53 .0 N.
Central eclipse at noon	9	8	49 .6	133	5 .2 W.	4	35 .1 S.
Central eclipse ends	9	10	25 .7	69	45 .2 W.	26	38 .0 S.
Eclipse ends	9	11	20 .9	83	11 .6 W.	23	21 .8 S.

The Planets.

The apparent paths of the planets among the stars during 1904 are shown in the diagrams Figs. 1 and 2.

Mercury starts out at once on the closed loop in Capricorn and Sagittarius, being visible as evening planet during the first few days of January, coming to conjunction Jan. 16, and becoming visible as morning star during the first days of February. Thence its course will be eastward and northward, while on the farther side of the Sun, until in May the planet comes between Earth and Sun again, being visible as evening star in the latter part of April and morning star in the first half of June. This time its retrograde movement produces an S-shaped loop in the curve of its path, just a little way southwest from the Pleiades. The third inferior conjunction of the planet with the Sun occurs in September, when another closed loop is described in Leo and Virgo, and the planet will be visible as evening star in the latter part of August and as morning star in the last days of September and first of October. Still a fourth loop of Mercury's path is begun in December but is only half completed at the end of the year. If the reader will

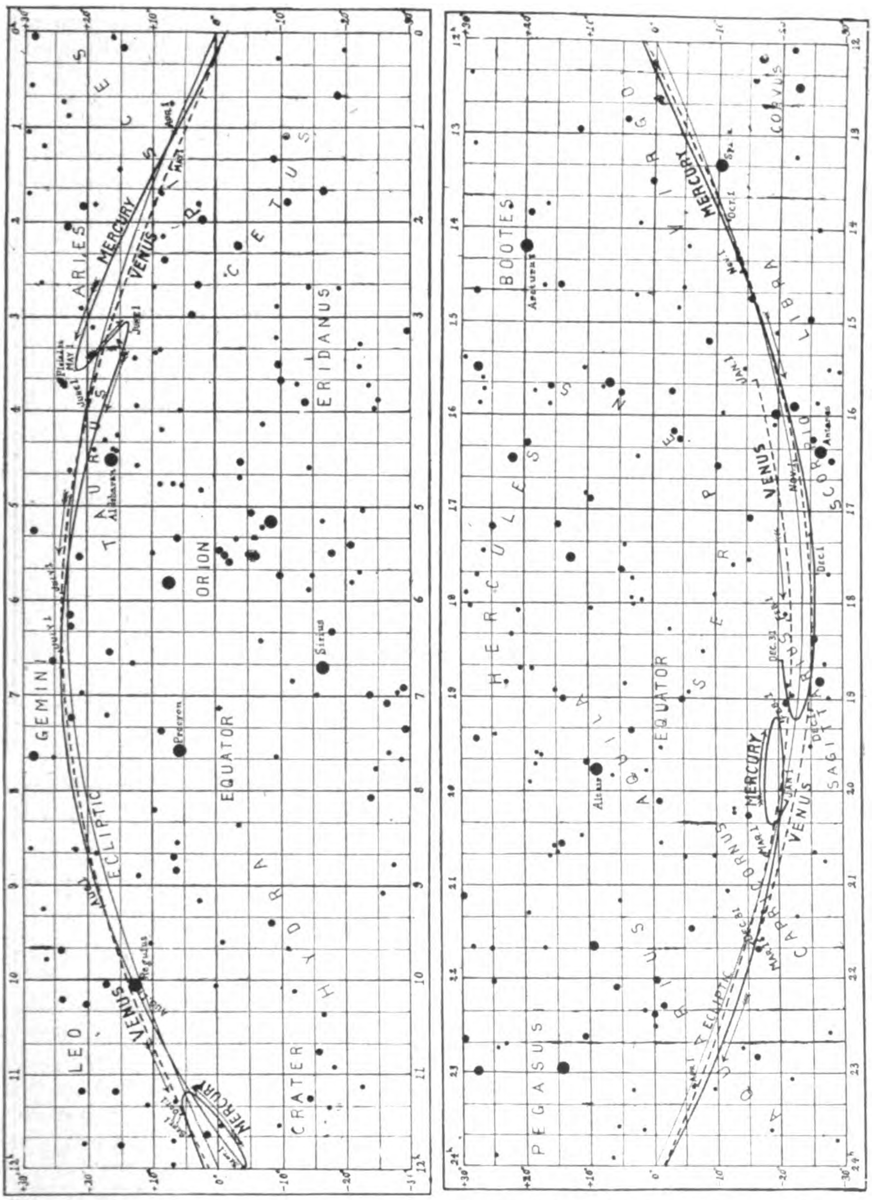


Fig. 1.—Diagram Showing the Apparent Movements of the Planets Mercury and Venus during 1904.

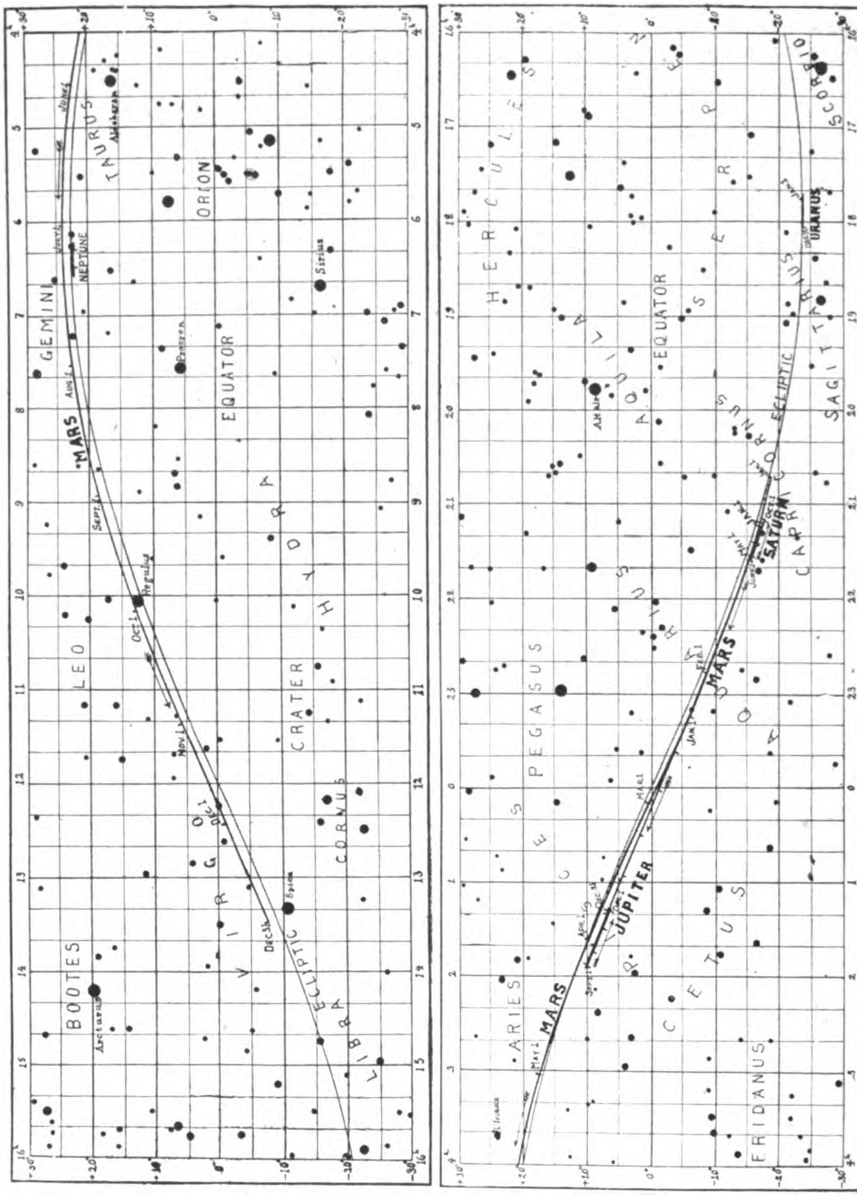


Fig. 2.—Diagram Showing the Apparent Movements of the Planets Mars, Jupiter, Saturn, Uranus and Neptune during 1904.

compare the diagrams of the path of Mercury in the January numbers of POPULAR ASTRONOMY for several years past, he will see that there is a great variety in the form of the apparent loops described by the planet. This is caused by the shifting of the points of conjunction westward around the planet's orbit; and as Mercury's orbit is inclined 7° to plane of the Earth's orbit, its movement is seen at a different angle from the Earth at each conjunction.

The dotted line showing Venus' apparent path for the year contains no loop since Venus does not come into inferior conjunction with the Sun this year. She will be at superior conjunction on July 7, and will be visible as evening star during the autumn and winter.

Mars also has no retrograde movement this year. His course begins in Capricorn near Saturn and follows the ecliptic closely, ending in Virgo not far from Spica. In the past month Mars has passed by Saturn and the two planets made a beautiful spectacle together. Their brightness was as nearly equal as one could estimate, the only difference being in the color of the apparent twin stars. In February 1904 Mars will pass Jupiter, the conjunction occurring Feb. 25 at 11 P. M., Central Standard time. Mars will then be 30′ north of Jupiter. Unfortunately at that hour of the night the two planets will be below the horizon in the United States.

Jupiter moves northeastward from Aquarius into Pisces, reaching 10° 12′ north declination in August, and coming to opposition Oct. 18. His movement will be retrograde from about the middle of August to the middle of December.

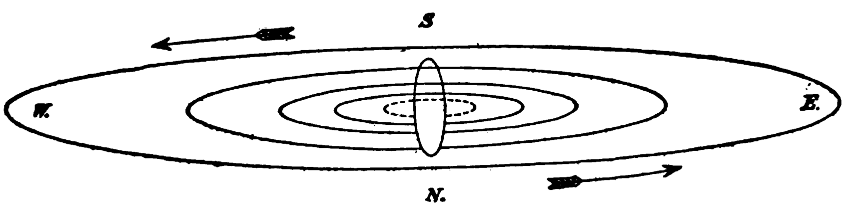


FIG. 3.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF JUPITER'S SATELLITES IN 1904.

The planet will be in fine position for observation in the autumn and early part of next winter. The diagram Fig. 3 shows the apparent movement of the satellites of Jupiter during the opposition of 1904.

Saturn describes a similar course to that of Jupiter, but is low down, in the

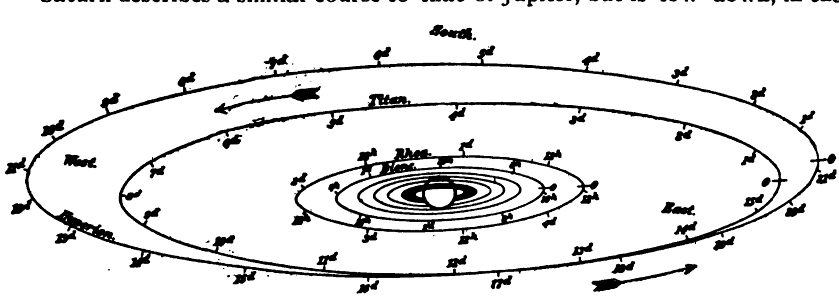
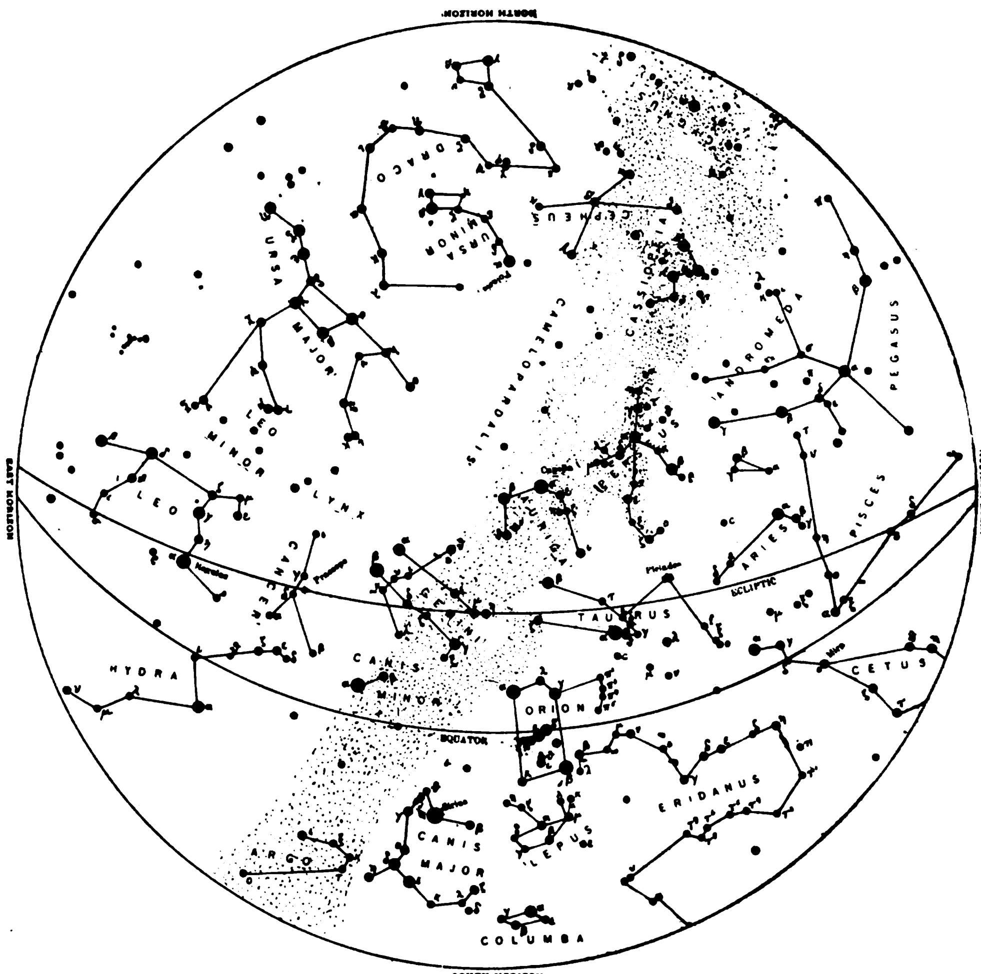


FIG. 4.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF THE SATELLITES OF SATURN IN 1904.

constellation Capricorn, so that at no time will the planet be in favorable position for observation in our latitude. The motion is direct until June 1, then ret-

rograde until Oct. 19, and after that direct. The apparent movements of seven of Saturn's satellites are shown in the diagram Fig. 4.

Uranus' course in Sagittarius is so short that its details cannot be shown on the chart plainly, but the motion is direct along the ecliptic until April 4, retrograde after that time until Sept. 5, then again direct. The planet will be always at too low an altitude for good observations in our latitude.



THE CONSTELLATIONS AT 9 P. M. FEBRUARY 1, 1904.

Neptune's course is also short, in the constellation Gemini. Starting westward it will pass the star μ Geminorum Jan. 16, the planet being then 15′ south of the star. It will continue to retrograde until March 14, then turning eastward will again pass the star μ on May 9, being then only 10′ south of the star. It will move eastward until Oct. 11 and then retrograde for the remainder of the year.

Comets.

Of the six comets whose return was due in 1903 only one, Brooks 1889 V, has at this writing been detected. In 1904, four comets whose periods are well determined are expected to return to perihelion, but only one of these will be so situated as to make us feel confident of its rediscovery.

1. Winnecke's Periodic comet is due at perihelion Jan. 21, 1904, according to the computations of C. Hillebrand (*A. N.* 3907), but will be in unfavorable position for observation, almost directly behind the Sun.

2. D'Arrest's comet is due about February 1, but is also on the farther side of the Sun and so not likely to be seen.

3. Tempel's second periodic comet is due at perihelion early in November. Its position will not be as favorable as at the last apparition in 1899, and since it was then very faint, there is some doubt about its being visible this year. If found at all it will probably be during the summer months.

4. Encke's famous comet will reach perihelion at the close of the year and will probably be visible as early as September. In November the comet will be comparatively near the Earth and should become quite a conspicuous telescopic object.

Phases of the Moon.

Washington Mean Time.

New Moon.		h	m	First Quarter.		h	m	Full Moon.		h	m	Last Quarter.		h	m
	......				......			Jan.	2	12	39	Jan.	9	4	2
Jan.	16	22	38	Jan.	25	3	33	Jan.	31	23	25	Feb.	7	16	48
Feb.	15	17	56	Feb.	23	18	0	Mar.	1	9	40	Mar.	8	7	52
Mar.	16	12	31	Mar.	24	4	28	Mar.	30	19	36	Apr.	7	0	45
Apr.	15	4	45	Apr.	22	11	46	Apr.	29	5	28	May	6	18	42
May	14	17	50	May	21	17	10	May	28	15	46	June	5	12	44
June	13	4	2	June	19	22	2	June	27	3	15	July	5	5	46
July	12	12	19	July	19	3	40	July	26	16	34	Aug.	3	20	54
Aug.	10	19	50	Aug.	17	11	19	Aug.	25	7	54	Sept.	2	9	50
Sept.	9	3	34	Sept.	15	22	4	Sept.	24	0	41	Oct.	1	20	44
Oct.	8	12	17	Oct.	15	12	46	Oct.	23	17	48	Oct.	31	6	5
Nov.	6	22	28	Nov.	14	7	27	Nov.	22	10	4	Nov.	29	14	30
Dec.	6	10	38	Dec.	14	4	59	Dec.	22	0	53	Dec.	28	22	38

Occultations.

The list of occultations, given as visible at Washington, in the American Ephemeris, numbers just 100. The list for January was given in the last number of Popular Astronomy. That for February is as follows:

Occultations Visible at Washington.

Date. 1904.		Star's Name.	Magnitude.	Immersion. Washington M.T. h	m	Angle f'm N pt. °	Emersion. Washington M.T. h	m	Angle f'm N pt. °	Duration. h	m
Feb.	1	*o* Leonis	3.8	17	53	115	18	47	292	0	54
	6	2 Libræ	6.3	18	12	107	19	34	292	1	22
	6	B.A.C. 4772	6.6	19	04	73	20	08	322	1	04
	8	49 Libræ	5.6	12	44	129	13	38	262	0	54
	22	W.B. ii, 1033	5.9	10	14	28	10	50	315	0	36
	24	B.A.C. 1526	5.8	11	24	73	12	22	288	0	58
	25	130 Tauri	5.5	6	49	106	8	09	250	1	20

Meteor Showers.

The following list contains the more brilliant showers, from a list of 90 meteoric showers whose radiant points are given by Mr. W. F. Denning in the *Companion to The Observatory:*

Date.	Radiant. α	δ	Remarks.
Jan. 2-3	230°	+ 53°	Swift; long paths.
Apr. 20-21	270	+ 33	Swift.
May 1-6	338	− 2	Swift; streaks.
July 28	339	− 11	Slow; long.
Aug. 10-12	45	+ 57	Swift; streaks. The Perseids.
Oct. 18-20	92	+ 15	Swift; streaks.
Nov. 14-16	150	+ 22	Swift; streaks. The Leonids.
Nov. 23-24	25	+ 43	Very slow; trains. The Andromedes.
Dec. 10-12	108	+ 33	Swift; short.

The Perseids, with a maximum on Aug. 11, are visible for a considerable period and their radiant exhibits a motion, to the E.N.E. among the stars of about 1° per day. Its position for July 19 should be δ 19°, δ + 50°, and on Aug. 16 α 53°, δ + 58°.

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered By	At	Local M. T.	h	m	R. A. h	m	Decl. °	′	Mag.
1903 MW	Wolf	Heidelberg	Oct. 27	12	01.2	3	18.9	+ 14	08	13.5
MX	Wolf	"	Nov. 14	8	02.8	3	04.9	+ 10	52	13.2

Numbering of Recently Discovered Asteroids.—In *A. N.* 3914 Dr. J. Bauschinger assigns the following numbers, to recently discovered asteroids whose orbits have been computed:

(507)	1903 LO	Dugan	Heidelberg
(508)	" LQ	"	"
(509)	" LR	Wolf	"
(510)	" LT	Dugan	"
(511)	" LU	"	"
(512)	" LV	Wolf	"

The planet 1903 LP was found to be identical with (406) [1895 CB]. 1902 JO, which had been assigned the number (489) has been shown to be identical with (470) Kilia. The number (489) will be assigned to the planet 1902 JM, for which the elliptic orbit computed is uncertain.

Definitive Elements of Comet 1894 I (Denning).—Dr. P. Gast, in the "Mitteilungen der Grossh. Sternwarte zu Heidelberg II," gives the results of a definitive computation of the orbit of Denning's periodic comet 1894 I from all the accessible observations. He obtains the following elements:

EPOCH 1894 MARCH 28.0 BERLIN M. T.

$$
\begin{aligned}
M_0 &= 6^\circ\ 10'\ 45''.20 \pm 0''.117\\
\pi &= 130\ \ 37\ \ \ 9\ .33 \pm 4\ .511\\
\Omega &= 84\ \ 22\ \ 20\ .38 \pm 5\ .801\\
i &= 5\ \ 31\ \ 45\ .96 \pm 0\ .239\\
\phi &= 44\ \ 17\ \ 55\ .50 \pm 1\ .889\\
\mu &= 478''.29684 \pm 0''.00958\\
\log a &= 0.5802061
\end{aligned}
$$

These elements make the period 7.419 years. The comet was not observed at its return in 1901 because of its unfavorable position. The next return will be near the close of 1908, when its position will be quite favorable for observation.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.]

U Cephei.

	d	h
Feb	2	13
	5	1
	7	13
	10	1
	12	12
	15	0
	17	12
	20	0
	22	12
	24	23
	27	11
	29	23

Z Persei

Feb.	3	13
	6	14
	9	16
	12	17
	15	18
	18	20
	21	21
	24	22
	28	0

Algol.

Feb.	2	0
	4	21
	7	18
	10	14
	13	11
	16	8
	19	5
	22	2
	24	22
	27	19

λ Tauri.

Feb.	3	17
	7	16
	11	14
	15	13
	19	12
	23	11
	27	10

R Canis Maj.

Feb.	1	17
	2	20
	4	0
	5	3
	6	6
	7	9
	8	13
	9	16
	10	19
	11	22
	13	2

R Canis Maj.

	d	h
Feb.	14	5
	15	8
	16	11
	17	15
	18	18
	19	21
	21	0
	22	4
	23	7
	24	10
	25	13
	26	17
	27	20
	28	23

RR (R^2) Puppis

Feb.	2	14
	8	0
	13	11
	18	21
	24	7
	29	18

S Cancri

Feb.	6	22
	16	10
	25	21

S Antliæ.

Feb.	1	5
	2	4
	3	3
	4	3
	5	2
	6	1
	7	1
	8	0
	8	23
	9	23
	10	22
	11	21
	12	21
	13	20
	14	19
	15	19
	16	18
	17	17
	18	17
	19	16
	20	15
	21	15
	22	14
	23	13
	24	13
	25	12

S Antliae

	d	h
Feb.	26	12
	27	11
	28	10
	29	10

S Velorum.

Feb.	5	22
	11	20
	17	19
	23	17
	29	16

δ Librae.

Feb.	2	3
	4	11
	6	19
	9	3
	11	11
	13	19
	16	3
	18	10
	20	18
	23	2
	25	10
	27	18

U Coronae.

Feb.	2	13
	6	0
	9	11
	12	22
	16	9
	19	20
	23	6
	26	17

R Aræ.

Feb.	1	15
	6	2
	10	12
	14	22
	19	8
	23	18
	28	5

U Ophiuchi.

Feb.	1	16
	2	12
	3	8
	4	4
	5	0
	5	21
	6	17
	7	13
	8	9
	10	1

U Ophiuchi.

	d	h
Feb.	10	21
	11	18
	12	14
	13	10
	14	6
	15	2
	15	22
	16	18
	17	14
	18	11
	19	7
	20	3
	20	23
	21	19
	22	15
	23	11
	24	7
	25	4
	26	0
	26	20
	27	16
	28	12
	29	8

Z Herculis.

Feb.	1	16
	3	14
	5	15
	7	14
	9	15
	11	14
	13	15
	15	14
	17	15
	19	13
	21	15
	23	13
	25	15
	27	13
	29	14

RX (X^2) Herculis.

Feb.	1	15
	2	13
	3	10
	4	7
	5	5
	6	2
	6	23
	7	21
	8	18
	9	15
	10	13
	11	10
	12	7

RX (X^2) Hercul.

	d	h
Feb.	13	5
	14	2
	15	0
	15	21
	16	18
	17	16
	18	13
	19	10
	20	8
	21	5
	22	2
	22	23
	23	21
	24	18
	25	16
	26	13
	27	10
	28	8
	29	5

RV (V^2) Lyræ.

Feb.	4	5
	7	0
	11	20
	15	10
	18	15
	22	5
	25	20
	29	10

U Sagittæ.

Feb.	1	7
	4	16
	8	1
	11	10
	14	19
	18	4
	21	14
	24	23
	28	8

SY (X^3) Cygni.

Feb.	2	0
	8	0
	14	0
	20	1
	26	1

SW (V^3) Cygni.

Feb.	5	2
	9	16
	14	6
	18	20
	23	9
	27	23

Minima of Variable Stars of the Algol Type.—Continued.

WW (Z^4) Cygni.	d	h	WW (Z^4) Cygni.	d	h	W Delphini.	d	h	Y Cygni.	d	h	Y Cygni.	d	h
			Feb.	25	14	Feb.	24	10	Feb.	8	9	Feb.	20	9
Feb.	1	10		29	1		29	6		9	17		21	17
	4	21	W Delphini.			Y Cygni.				11	9		23	9
	8	8								12	17		24	17
	11	18	Feb.	5	5	Feb.	2	9		14	9		26	9
	15	5		10	0		3	17		15	17		27	17
	18	16		14	19		5	9		17	9		29	9
	22	3		19	15		6	17		18	17			

Variable Stars of Short Period not of the Algol Type.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
S Crucis	Feb. 1	16	Feb. 3	4	S Crucis	Feb. 15	18	Feb. 17	6
κ Pavonis	1	16	5	11	β Lyrae	15	22	19	0
SU Cygni	2	7	3	15	S Normae	16	10	20	20
S Muscae	2	11	5	22	T Crucis	16	21	18	22
V Centauri	2	11	3	22	RV Scorpii	17	9	18	18
β Lyræ	3	0	6	2	T Vulpeculae	17	6	18	16
S Trianguli Austr.	3	2	5	4	SU Cygni	17	16	19	0
δ Cephei	3	3	4	18	κ Pavonis	17	20	21	15
T Monocerotis	3	8	11	6	V Velorum	18	4	19	3
T Crucis	3	11	5	12	R Crucis	18	8	19	17
T Vulpeculae	4	1	5	10	T Velorum	18	16	20	1
ζ Geminorum	4	5	9	5	V Centauri	18	23	20	10
T Velorum	4	18	6	3	δ Cephei	19	6	20	21
V Velorum	5	1	6	0	S Crucis	20	10	21	22
W Geminorum	5	2	7	17	W Geminorum	20	14	23	5
RV Scorpii	5	3	6	13	V Carinae	20	15	22	19
SU Cygni	6	3	7	11	SU Cygni	21	12	22	20
S Crucis	6	9	7	21	T Vulpeculae	21	19	23	4
W Virginis	6	12	14	17	S Muscae	21	19	25	6
R Crucis	6	16	8	1	S Triang. Austr.	22	1	24	3
S Normae	6	16	11	2	β Lyrae	22	9	25	16
V Carinae	7	5	9	9	V Velorum	22	13	23	12
V Centauri	7	23	9	10	T Velorum	23	8	24	17
T Vulpeculae	8	12	9	21	RV Scorpii	23	8	24	18
δ Cephei	8	12	10	3	T Crucis	23	14	25	15
S Triang. Austr.	9	9	11	11	W Virginis	23	19	31	23
T Velorum	9	9	10	18	R Crucis	24	4	25	13
V Velorum	9	10	10	9	V Centauri	24	11	25	22
β Lyrae	9	11	12	18	ζ Geminorum	24	13	29	13
κ Pavonis	9	18	13	13	δ Cephei	24	15	26	6
SU Cygni	9	23	11	7	S Crucis	25	3	26	15
T Crucis	10	4	12	5	SU Cygni	25	8	26	16
S Crucis	11	1	12	13	κ Pavonis	25	22	29	17
RV Scorpii	11	4	12	14	S Normae	26	4	30	14
S Muscae	12	3	15	14	T Vulpeculae	26	5	27	14
TX Cygni	12	6	17	9	V Velorum	26	22	27	21
R Crucis	12	12	13	21	TX Cygni	26	23	32	2
W Geminorum	12	20	15	11	V Carinae	27	8	29	12
T Vulpeculae	12	22	14	7	T Velorum	27	23	29	8
V Centauri	13	11	14	22	W Geminorum	28	8	30	23
V Velorum	13	19	14	18	S Triang.Austr.	28	9	30	11
δ Cephei	13	21	15	12	β Lyrae	28	20	31	22
V Carinae	13	22	16	2	SU Cygni	29	5	30	13
T Velorum	14	1	15	10	RV Scorpi	29	9	30	19
ζ Geminorum	14	9	19	9	S Crucis	29	19	31	7
X Cygni	14	18	21	13	V Centauri	29	23	31	10
S. Triang. Austr.	15	17	17	19					

Approximate Magnitudes of Variable Stars Dec. 10, 1903.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	14*f*
T Cassiop.	0	17.8	+55	14	8
R Androm.	0	18.8	+38	1	10*i*
S Ceti	0	19.0	− 9	53	10*d*
W Cassiop.	0	49.0	+58	1	*f*
S "	1	12.3	+72	5	12*d*
R Piscium	1	25.5	+ 2	22	12*d*
R Trianguli	1	31.0	+33	50	6
U Persei	1	52.9	+54	20	8
R Arietis	2	10.4	+24	36	8*i*
o Ceti	2	14.3	− 3	26	9
S Persei	2	15.7	+58	8	9*d*
R Ceti	2	20.9	− 0	38	12*d*
U "	2	28.9	−13	35	12*d*
R Persei	3	23.7	+35	20	8
R Tauri	4	22.8	+ 9	56	12*i*
S "	4	23.7	+ 9	44	14*f*
R Aurigæ	5	9.2	+53	28	9*i*
U Orionis	5	49.9	+20	10	12*d*
R Lyncis	6	53.0	+55	28	9*d*
R Gemin.	7	1.3	+22	52	11*d*
S Canis Min.	7	27.3	+ 8	32	8*i*
R Cancri	8	11.0	+12	2	8*d*
V "	8	16.0	+17	36	11*i*
S Hydrae	8	48.4	+ 3	27	9*i*
T "	8	50.8	− 8	46	10*i*
R Leo. Min.	9	39.6	+34	58	9*d*
R Leonis	9	42.2	+11	54	8*d*
R Urs. Maj.	10	37.6	+69	18	12*d*
R Comae	11	59.1	+19	20	*f*
T Virginis	12	9.5	− 5	29	*f*
R Corvi	12	14.4	−18	42	10*i*
Y Virginis	12	28.7	− 3	52	*f*
T Urs. Maj.	12	31.8	+60	2	9*d*
R Virginis	12	33.4	+ 7	32	11*d*
S Urs. Maj.	12	39.6	+61	38	9*d*
U Virginis	12	46.0	+ 6	6	9
V "	13	22.6	− 2	39	*f*
R Hydrae	13	24.2	−22	46	*s*
S Virginis	13	27.8	− 6	41	9*d*
R Can. Ven.	13	44.6	+40	2	12*d*
S Bootis	14	19.5	+54	16	8*i*
R Camel.	14	25.1	+84	17	9*d*
R Bootis	14	32.8	+27	10	12*d*
S Librae	15	15.6	−20	2	*s*
S Serpentis	15	17.0	+14	40	*f*
S Coronae	15	17.3	+31	44	12*f*
S Urs. Min.	15	33.4	+78	58	8
R Coronae	15	44.4	+28	28	6
V "	15	45.9	+39	52	*u*
R Serpentis	15	46.1	+15	26	*s*
R Herculis	16	1.7	+18	38	*s*
R Scorpii	16	11.7	−22	42	*s*
S "	16	11.7	−22	39	*s*
U Herculis	16	21.4	+19	7	*s*
R Ursae Min.	16	31.3	+72	28	9
W Herculis	16	31.7	+37	32	10*i*
R Draconis	16	32.4	+66	58	*f*
S Herculis	16	47.4	+15	7	*s*
R Ophiuchi	17	2.0	−15	58	*s*
T Herculis	18	5.3	+31	0	8*i*
R Scuti	18	42.2	− 5	49	*s*
R Aquilae	19	1.6	+ 8	5	*f*
R Sagittarii	19	10.8	−19	29	*s*
S "	19	13.6	−19	12	*s*
R Cygni	19	34.1	+49	58	8*d*
RT "	19	40.8	+48	32	9*d*
X "	19	46.7	+32	40	6*d*
S Cygni	20	3.4	+57	42	*f*
RS "	20	9.8	+38	28	7
R Delphini	20	10.1	+ 8	47	11*d*
U Cygni	20	16.5	+47	35	11
V "	20	38.1	+47	47	12*i*
T Aquarii	20	44.7	− 5	31	*f*
R Vulpec.	20	59.9	+23	26	8*i*
T Cephei	21	8.2	+68	5	8*i*
S "	21	36.5	+78	10	8*i*
S Lacertae	22	24.6	+39	48	9*d*
R "	22	38.8	+41	51	12*d*
S Aquarii	22	51.8	−20	53	13*f*
R Pegasi	23	1.6	+10	0	11*d*
S "	23	15.5	+ 8	22	9*i*
R Aquarii	23	38.6	−15	50	8*i*
R Cassiop.	23	53.3	+50	50	11*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, McCormick, Eadie, Vassar College and Harvard Observatories, Dec. 10, 1903.

New Variable Stars 32-54.1903 Orion.—These are all in the great nebula of Orion and were announced by Professor Max Wolf in *A.N.* 3899. They were overlooked in our previous notes. Their positions for 1900.0 and their magnitudes are as follows:

Provis. Notation.	R. A. h	m	s	Decl. °	′	″	Mag.
32.1903	5	26	59.2	−4	31	26	14.0 — < 15
33.1903	5	27	13.6	−5	7	1	11.3 — 15.0
34.1903	5	27	16.6	−7	32	45	13.3 — 14.0
35.1903	5	27	45.0	−7	38	47	13.6 — < 14
36.1903	5	28	37.6	−5	16	17	13.8 — 15.0
37.1903	5	28	59.5	−4	52	3	13.0 — 15.2
38.1903	5	29	23.3	−6	40	16	13.0 — 15.0
39.1903	5	29	55.8	−4	44	16	12.5 — 14.0
40.1903	5	30	0.5	−5	50	49	12.5 — 14.0
41.1903	5	30	16.3	−5	50	36	12.0 — 14.5
42.1903	5	30	20.8	−4	49	45	12.7 — < 14
43.1903	5	30	27.1	−5	38	48	12.3 — < 14
44.1903	5	30	58.1	−4	51	15	12.8 — < 15
45.1903	5	30	58.9	−6	54	40	12.5 — 15.0
46.1903	5	31	8.4	−6	46	26	12.6 — < 14
47.1903	5	33	38.4	−7	19	14	13.5 — 15.0
48.1903	5	35	57.8	−8	8	32	13.0 — 15.0
49.1903	5	36	36.0	−4	11	17	9.8 — < 15
50.1903	5	30	39.4	−6	49	14	12.5 — < 14
51.1903	5	32	18.4	−3	35	15	13.0 — 14.0
52.1903	5	34	31.9	−4	57	26	12.5 — 13.2
53.1903	5	35	57.9	−8	7	43	12.8 — 13.9
54.1903	5	43	16.1	−5	43	36	12.7 — 13.5

The last five are designated as possibly variable; all the others as certainly variable.

Nomenclature of Newly Discovered Variable Stars.*

Provis. Notation A. N.	Name.	Position for 1900.0 R A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
11.1903	R U Andromedæ	1	32	47	+38	9.5	+3.49	+0.31
15.1903	Z Cephei	2	12	48	+81	13	+7.81	+0.28
56.1903	RR Cephei	2	29	23	+80	42.3	+8.03	+0.27
14.1902	Z Persei	2	33	40	+41	46.1	+3.81	+0.26
22.1903	X Camelopardalis	4	32	36	+74	56	+7.68	+0.12
5.1903	RS Tauri	5	46	3	+15	51.3	+3.45	+0.02
1.1903	Z Aurigæ	5	53	39	+53	18.0	+4.86	+0.01
20.1903	W Camelopardalis	6	12	0	+75	32	+8.25	−0.02
14.1903	RS Geminorum	6	55	14	+30	39.8	+3.84	−0.08
9.1903	Z Geminorum	7	1	36	+22	41.0	+3.61	−0.09
16.1903	RR Monocerotis	7	12	27	+1	16.6	+3.10	−0.10
13.1903	RR Geminorum	7	15	11	+31	4.2	+3.83	−0,10
21.1903	Y Camelopardalis	7	27	39	+76	16.9	+8.15	−0.12
4.1902	Y Geminorum	7	35	16	+20	39.6	+3.53	−0.13
2.1903	Y Draconis	9	31	5	+78	18.2	+6.98	−0.27
3.1903	W Ursæ Maj.	9	36	44	+56	24.6	+4.25	−0.27
4.1903	Z Draconis	11	39	49	+72	49.0	+3.45	−0.33
57.1903	T Ursæ Min.	13	32	38	+73	56.4	+1.25	−0.31
29.1903	ST Herculis	15	47	47	+48	47.1	+1.79	−0.18
18.1902	W Coronæ	16	11	50	+38	2.7	+2.14	−0.15
31.1903	SU Herculis	17	44	42	+22	34	+2.52	−0.02
76.1901	RT Ophiuchi	17	51	51	+11	10.9	+2.81	−0.01
19.1903	RZ Lyræ	18	39	54	+32	41.7	+2.23	+0.06
17.1903	RY Lyræ	18	41	15	+34	34.0	+2.17	+0.06
17.1902	RW Lyræ	18	42	7	+43	31.9	+1.82	+0.06
10.1903	RX Lyræ	18	50	27	+32	42.3	+2.23	+0.07
55.1903	VW Cygni	20	11	21	+34	11.8	+2.31	+0.18
21.1902	V Sagittæ	20	15	46	+20	47.3	+2.65	+0.19
16.1902	Z Delphini	20	28	3	+17	6.2	+2.74	+0.20

* From Supplement to Nos. 549-550 of the *Astronomical Journal.*

Nomenclature of Newly Discovered Variable Stars.—Continued.

Provis. Notation A. N.	Name.	Position for 1900.0 R. A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
15.1902	Y Delphini	20	36	52	+ 11	30.9	+ 2.86	+ 0.21
58.1903	VX Cygni	20	53	34	+ 39	47.5	+ 2.26	+ 0.23
20.1902	VV Cygni	21	2	20	+ 45	22.6	+ 2.12	+ 0.24
19.1902	RT Pegasi	21	59	49	+ 34	38.2	+ 2.61	+ 0.29
	RS Andromedæ	23	50	19	+ 48	4.9	+ 3.01	+ 0.33
12.1903	Nova Geminornm	6	37	49	+ 30	2.6	+ 3.83	— 0.05

Nomenclature of Newly Discovered Variable Stars.—Continued.

Provis. Notation A. N.	Name.	Chart-Place. R. A. h	m	s	Decl. °	′	Magnitude. Max.	Min.	
11.1903	RU Andromedæ	1	30	11	+ 37	55.6	9	13	*ph*
15.1903	Z Cephei	2	7	6	81	0	9.10	< 13	*ph*
56.1903	RR Cephei	2	24	15	80	30.2	9	< 13	*ph*
14.1902	Z Persei	2	30	50	41	34.3	9	12	*v*
22.1903	X Camelopardalis	4	26	48	74	50	9	13	*ph*
5.1903	RS Tauri	5	43	28	15	50.3	8.9	10.11	*v*
1.1903	Z Aurigæ	5	50	3	53	16.9	9	11	*v*
20.1903	W Camelopardalis	6	5	48	75	32	10.11	12	*ph*
14.1903	RS Geminorum	6	52	21	30	43.3	9.10	11.12	*ph*
9.1903	Z Geminorum	6	58	53	22	44.9	9.10	< 12	*v*
16.1903	RR Monocerotis	7	10	7	1	21.2	9	< 13	*ph*
13.1903	RR Geminorum	7	12	18	31	9.0	10	11.12	*ph*
21.1903	Y Camelopardalis	7	21	30	76	22.3	9.10	< 11.12	*ph*
4.1902	Y Geminorum	7	32	37	20	45.3	8.9		*ph*
2.1903	Y Draconis	9	25	47	78	30.1	9	13	*ph*
3.1903	W Ursæ Maj.	9	33	32	56	36.7	8	9	*v*
4.1903	Z Draconis	11	37	12	73	4.0	9.10	12.13	*ph*
57.1903	T Ursæ Min.	13	31	42	74	10.2	9	< 13	*ph*
29.1903	ST Herculis	15	46	27	48	55.4	7.8	8.9	*v*
18.1902	W Coronæ	16	10	14	38	9.6	7.8	13	*v*
31.1903	SU Herculis	17	42	48	22	35	10	< 12	*ph*
76.1901	RT Ophiuchi	17	49	45	11	11.5	9	< 10	*v*
19.1903	RZ Lyræ	18	38	14	32	39.1	10	11.12	*ph*
17.1903	RY Lyræ	18	39	38	34	31.4	10	12	*ph*
17.1902	RW Lyræ	18	40	45	43	29.2	9	< 12	*ph*
10.1903	RX Lyræ	18	48	46	32	39.0	11	< 15	*ph*
55.1903	VW Cygni	20	9	37	34	3.7	9.10	11.12	*ph*
21.1902	V Sagittæ	20	13	47	20	39.0	9.10	13	*ph*
16.1602	Z Delphini	20	26	0	16	57.2	9	< 11	*ph*
15.1902	Y Delphini	20	34	43	11	21.5	9.10	< 13	*v*
58.1903	VX Cygni	20	51	52	39	37.2	9	9.10	*ph*
20.1902	VV Cygni	21	0	45	45	11.9	11	< 12	*ph*
19.1902	RT Pegasi	21	57	51	34	25.3	9.10	13.14	*v*
	RS Andromedæ	23	48	4	47	49.5	7.8	8.9	*ph*
12.1903	Nova Geminorum	6	34	56	+ 30	5.0	5	—	—

The committee for the A. G. Catalogue of Variable stars: Dunér, Hartwig, Müller, Oudemans.

New Variable Star 61.1903 Cygni.—In *A. N.* 3915 Mr. A. Stanley Williams announces this new variable, which is

BD + 39°4423 (9.5), R. A. = 20^h 58^m $42^s.9$; Decl. = + 39° 23′.7 (1855)

The range of variation is from about $8^m.8$ at maximum to $9^m.5$ at minimum in a period of 7.857 days. From minimum to maximum the interval is 2.1 days, and from maximum to minimum 5.76 days. Future maxima should occur Jan. 9.24, 17.09, 24.95, Feb. 1.81, 8.66, 16.52, 24.38 Greenwich civil time.

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	d	h		d	h		d	h		d	h
Feb.	1	13	Feb.	9	14	Feb.	17	16	Feb.	25	12
	2	16		10	13		18	14		26	15
	3	14		11	16		19	13		27	14
	4	13		12	14		20	16		28	12
	5	16		13	13		21	14		29	15
	6	14		14	16		22	13			
	7	13		15	14		23	15			
	8	16		16	13		24	14			

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$.

	d	h		d	h		d	h		d	h
Feb.	1	19	Feb.	8	19	Feb.	15	20	Feb.	23	21
	2	19		9	20		16	20		24	21
	3	19		10	20		17	21		25	22
	4	19		11	20		18	21		26	22
	5	19		12	20		19	21		27	22
	6	19		13	20		20	21		28	32
	7	19		14	20		22	21		29	22

Maxima of UY Cygni.

Period $13^h\ 27^m\ 21^s$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Feb.	1	15	Feb.	9	11	Feb.	17	8	Feb.	25	4
	2	18		10	14		18	11		26	7
	3	21		11	17		19	14		27	10
	5	0		12	20		20	16		28	13
	6	3		13	23		21	19		29	16
	7	6		15	2		22	22			
	8	8		16	5		24	1			

GENERAL NOTES.

This number indicates the beginning of changes in the plan and management of this magazine to which reference has already been made. The plan now unfolding has been a cherished one for a long time past, its fulfillment being possible because of favoring circumstances we can now control. These consist mainly in better office facilities, better and more ready printing, finer engraving, ample assistance for translations, and, most important of all, largely increased help in securing original articles to set forth, month by month, the condition and progress of astronomy in general and American astronomy in particular.

In this broader plan it is not our aim to seek an international prominence, or a purely professional cast of detailed methods of astronomy work, but, rather to confine our efforts to work in the home field to relate it, and to unify it more closely and effectively for all interested or even remotely concerned. If it should be possible to unite only a small part of the available energy, now largely unused in this way, in the different parts of the United States, who can measure the ample results of such coöperation for the benefits of astronomy in numberless ways. In this worthy endeavor we hope for the ready response of very many to our appeal for such assistance as may be easily rendered because it is only the little that will be asked of the many.

From the beginning we have endeavored to keep the subscription price of this magazine lower than any other of its kind and size to be found anywhere as far as we know. Because writers have furnished articles free of charge, and because we have had our own office and have given our time to this work without financial return, we have been able always to meet expenses and pay cash in advance for needed annual supplies. Whether this can be done in the future without an increase in the subscription price remains to be proved. It can be done if the merit of the publication is what it should be, and interest in its support is sufficiently general.

Auroral Band.—In a recent letter from Dr. D. L. Stewart, of the Cincinnati Observatory is given an account presumably of the Auroral band which was so generally observed in August last. The statement in the words of the observer was as follows:

"There appeared in the sky overhead at the resort of Omena on Great Traverse Bay, Mich., one evening in August what was a mystery to common observers. It extended S. S. E., where it seemed to touch the horizon across the bay, and in a straight line directly overhead reaching in the opposite direction, to within forty or fifty degrees of the horizon. To the naked eye it appeared to be more distant than high clouds.

It seemed to be brighter or denser along the center line of it, and was, I should think, one degree in width, or two at most. When I first saw it, the width was the same throughout its entire length, with the exception of the visible end which tapered abruptly and faded.

The time of night was between nine and ten o'clock P. M. Its duration was ten or twenty minutes after I saw it. It became gradually shorter and narrower, the south-eastern end also appearing and then receding slowly from the horizon, during which time its brightness was diminishing.

Just before it faded out, it assumed a blotched appearance after which it was quickly gone. When its light was strongest, it was brighter than the Milky Way, but I saw no color."

Auroral Band, Lincoln, Ill.—At first, not long after dark, a faint, narrow, irregular streak of light shot up from the eastern horizon, gradually becoming brighter till it nearly reached the zenith, when a similar appearance showed in the west, till the two met, overhead, forming a band from horizon to horizon, through the zenith, white and well-defined, and perhaps five degrees wide. At its brightest there was a wavy, cloud-like motion from east to west like drifting clouds of thin steam. This band was, perhaps, an hour in forming, and as long in completely disappearing, a short time after which, a slight streak appeared again in the east, but soon vanished.

The band in forming moved a little to the south of its first position, in the east. An Aurora was visible all the time in the north, and increased in brilliancy after the band disappeared. No disturbance was noticed in the railroad electric instruments.

This phenomenon seems to have extended from Montana to Maine. It would be of interest to know if it extended around the world. O. A. ALLEN

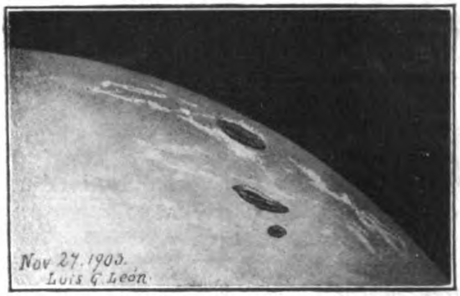
LINCOLN, ILL.

Aug. 21, 1903.

The Solar Activity.—From October last the Sun has begun to show great activity. No doubt the time of maximum is approaching. The lovers of astronomy have now a good opportunity to direct their attention to the Sun.

I observe the Sun every morning, at seven, and I keep a collection of drawings of my observations, which drawings are useful in comparing old and new spots.

November last was a good month for solar observations; not a single day was the Sun without spots and there were some very fine groups. December has also shown great activity on the Sun and the indications are that it will continue. On the first day of December appeared one new spot on the south-east limb,



and all around it there were great and brilliant faculæ. There were also visible two large spots north and a group south.

On the second day two new spots made their appearance at the same limb. On this day one of the large spots of the north had the shape of a heart. On the third day the two new spots of the day before had developed considerably. The south-east group was magnificent on the fifth day.

Sunday sixth, appeared one new spot on the north-east limb. I must say that this spot I observed at 4 o'clock in the afternoon; in the morning nothing was visible on that region. Monday 7th, another new spot showed at the same region. On Thursday 10th, I noticed a new and fine spot at the south-east limb. The faculæ on this region were indeed unusually large. On the 11th, 12th, and 13th my attention was specially directed to the two large sun-spots which appeared on the 6th and 7th. They are large with the penumbra perfectly defined and the filaments of a grayish color. The faculæ have been specially large and brilliant these days. LUIS G. LEON.

MEXICO.

December 13th, 1903.

The Terminator of Venus.—While observing Venus on Nov. 21st at 7:30 A. M. in a clear and serene sky, very distinct markings, curvilinear in form, and extending well towards the periphery of the disc were clearly seen, resembling in a general way those seen on the lunar surface to unassisted vision, the accompanying sketch giving the approximate location; this is my first opportunity of seeing more than the usual irregular terminator with its dark shading. The image was steady and beautifully defined, but a subsequent observation perhaps 30 minutes later, found the disc a moving mass with no detail. The instrument used was a reflector by Mr. Brashear, with 8½-inch speculum. WESTON WETHERBEE.

VENUS, Nov. 21, 1903.

BARRE, N. Y., Nov. 27, 1903.

Leonids at Providence, R. I.—At the Ladd Observatory, observations were planned for November 13, 14 and 15 (astronomical reckoning). The first of these nights was wholly cloudy and the last partly overcast, but the second was beautifully clear. The sky east of the meridian was carefully watched from 13^h to 17^h, especial attention being given to the region within 30° of Leo. The total count by two observers was 20 Leonids and 24 other meteors. Eighteen of the former were charted, and were well distributed in all directions from the radiant point. The position of the radiant point determined from them is R. A. $10^h\ 1^m$, Decl. $+21° 48'$. In 1901, on the corresponding night (November 14, $12^h.35 - 17^h.30$), 91 were charted. In 1902, cloudy weather prevailed. The small number observed this year was not due to unfavorable conditions, but shows that few entered the atmosphere within the region of observation.

PROVIDENCE, R. I. November 24, 1903. W. UPTON.

Approach of Sunspot Maximum.—During the month of July we observed at Wake Forest, N. C., as many as ninety sunspots—part of them north of the solar equator, and part south, as illustrated in "Sunspots in July" in the August number of POPULAR ASTRONOMY. No such persistence and rapid succession of

spots and groups has occurred in the past five or six years. They were certainly heralds of an approaching sunspot maximum. These numerous July spots were indeed all relatively quite small. And size, as well as number, is an element in such a maximum. This element of size, however, has already begun to change. In October a very large group of spots darkened the Sun's disk. Using a shield of smoked glass it could be seen with the naked eye. When first observed here, at noon Oct. 14th, it was larger than any group seen since 1892. By the 18th of October it reached the Sun's western limb and passed out of view. But in due time, it reappeared to us on the Sun's eastern edge. It was there in full view when observed in the early morning of Oct. 30th, but its form was altered. Early in the month it was somewhat rectangular in shape. Its vast extent excited general interest. As estimated by good authorities it was 120,000 miles long and 40,000 miles broad. That is, it covered an area more than 24 times the entire surface of our Earth.

When seen again at Wake Forest, Oct. 30, it had divided into three great spots. Nov. 3, when well advanced into view, it was still more changed. One spot had almost closed, each of the other two had expanded, and grouped about them were 18 relatively small spots.

With like mutations it remained a conspicuous object until Nov. 12, when it again passed the Sun's western edge out of view.

Meanwhile, two other extensive groups appeared. The first of these was observed Oct. 26, just as it rounded the Sun's eastern limb. It was somewhat triangular in shape, and about one-third the size of the great group which has now twice passed the western limb of the Sun. Varying in aspect from day to day, it too passed the western limb Nov. 7.

The other group, the third in order of these extensive disturbances, was seen near the east limb Nov. 4. Next day, when more fully in view, it showed four very large spots, with fifteen smaller ones clustered about them. Its area exceeded that of its immediate predecessor, and its changes of form were more surprising. It passed out of view about Nov. 16.

These three great groups, in view within a month, together exceeded in extent forty times the entire surface of our Earth. They amply furnish the element of size, as the July sunspots gave that of number. Number and size indicate growing solar disturbance, and evidence unmistakably an approaching sunspot maximum.

The period from one maximum to the next being about eleven years, we may expect the one now approaching to culminate in or near the year 1904. It is a favorable time for the study of interesting questions touching solar conditions. I make a single suggestion as to the nature of sunspots.

They are often referred to as furious solar storms or cyclones. Unquestionably, in spot areas the surface material is tossed and torn asunder—and adjacent glistening faculæ consist of solar matter thrown into widely irregular masses piled many times mountain high.

But can there be at the Sun's fiercely hot surface any such differences of temperature as are essential to movements in anywise analogous to storms terrestrial?

Moreover, we note on the Sun a fairly sharp boundary between the dark disturbed areas and the adjoining bright regions; while on our Earth there is always a gradual transition from regions of storm to regions of calm. Again, storms sweep the Earth's surface, while motion in sunspots, or seeming motion, is

mainly vertical. Such considerations tend to the view that sunspots are formed by internal, uprushing energy, rather than by surface, storm-like action.

In either view allowing remoteness of resemblance, may we not liken sunspots to our earthquakes, rather than to our wind storms? Is it objected that a sunspot covers a great area, and often persists for weeks or months? True, our earthquakes usually produce *visible* results only in small areas, and quickly subside; but often they are *felt* throughout an extensive territory.

The recent earthquake, Nov. 4, which caused consternation in the city of St. Louis, was felt in eight states—Missouri, Illinois, Indiana, Kentucky, Tennessee, Mississippi, Louisiana and Arkansas. An earthquake in the year 357 A. D., in that ill fated region which we now know as politically convulsed Macedonia, was so widespread that it swallowed up 150 cities. The great earthquake of 1755 which destroyed Lisbon with its 50,000 people, destroyed or damaged several other cities of Portugal and some in Spain and in Morocco, and extended its disasters east to Arabia and west to the island of Madeira. In 394 A. D., an earthquake in Europe wrought its destruction of city after city for fully one month; and one in Constantinople in the year 480 A. D. convulsed that region for forty days.

In point of fact, then, as regards both extent and duration there is analogy between the sunspot and the earthquake. From these several considerations—probable uniform temperature, sharpness of demarkation, seeming preponderance of vertical motion, and analogy in extent and duration—we may say the spots are in no sense solar surface storms, but rather deep seated solar disturbances.

As shown, the first great sunspot in October was of vast extent and displayed its vigor for more than a month. The sunspot maximum now at hand promises abundant opportunity for noting other such outbursts of solar energy, some perhaps on a still grander scale.

J. F. LANNEAU.

Is the Universe Limited in Extent and Spherical in Form?— We have received a communication from a very intelligent and thoughtful reader of this publication in regard to the open question of the extent and form of the material universe. Our correspondent is evidently not satisfied with the positions taken by Mr. Wallace, in our last October number, whose arguments therein tended to show that our universe is both limited in extent and spherical in form. The objections offered are:

1. The mind can form no conception of anything infinite.

This statement is too broad. Since the time of Newton especially mathematicians have dealt with infinities and infinitessimals as easily and certainly as with finites through the methods of the Calculus. They must know much about infinities or they would know less about finites.

2. The boundary between the finite and the infinite is a barrier the human mind cannot cross.

If our correspondent means a hard and fast line somewhere in the realm of physical reality, he may be right. But this is not the sense in which the scholars in mathematics speak of the limits of the finite and of the infinite. The mathematician will pass from the finite, over its limits, into the infinite just as easily as a lawyer will pass from one point in his brief to another which is a definite and a logical sequence in the course of his reasoning.

3. Is space filled with matter and force or only partly filled?

Our correspondent thinks that if space is only partly filled (as Mr. Wallace contends in the article above referred to) by a finite material system of stars, it will follow as a necessary consequence, that this finite system must have a center of gravity somewhere, and that if the force of gravity extends throughout this universe, all matter must tend to this center, and be in a state of condensation towards it, unless a dynamic equilibrium is maintained by some force opposed to gravity. So far as we know this equilibrium of all bodies is maintained by a motion of revolution or rotation. The imaginary spherical universe must then either revolve around its own center of gravity or rush to ruin on its center. So far as we know it is doing neither.

The above statement is nearly in our correspondent's own language, and in the main is good reasoning from known facts, as far as it goes. He doubtless knows "That the mills of the gods grind slowly, but they grind exceeding fine." The whole difficulty in framing decisive argument, in such great questions as these, is, the lack of data for generalization in theory or presumptive inference. Our real data have scarcely yet reached the stage of more than plausible inference. We can not certainly say whether or not the universe is limited. From the behavior of comets and new stars, so called, we know something of the startling possibilities of matter, ether force, and motion; but we need to know more before we can claim knowledge of more than plausible inferences regarding the extent and form of the great physical universe.

The Stellar Heavens by J. Ellard Gore. F. R. A. S., is a new book published by Chatto & Windus of 111 St. Martin's Lane, London, W. C. England. It is an introduction to the study of the stars and nebulæ; or that part of sidereal astronomy which deals with the number, motions, distances, etc., of these two classes of celestial objects. In a small book of 128 pages, the descriptions and the details only of the more prominent and interesting stars and nebulæ could be given; and the information furnished is brought up to date, and is useful both to beginners, as well as to the more advanced students of the stellar universe.

The contents of the book is divided into five chapters, with the following order of topics: The stars; double, multiple, and binary stars; variable stars; star clusters and nebulæ, and the stellar universe. Under the first topic, the stars, the author speaks of the constellations historically and critically with leading facts in detail, supplemented by notes from the appendix. He places the total number of the stars visible in the largest telescopes at "probably about 100,000,000." In this connection is found an interesting paragraph or two relating to the number of stars found in old and new catalogues and atlases of the stars; especially that estimate from Herschel star guages at a total of 200,000,000, or another from the richness of the Galaxy 82,000,000, or, from a spot near Cygnus in the Galaxy taken by Dr. Roberts in 1898, showing 30,000 stars in the space of three and a half square degrees. That would mean a total of 360,000,000. But when photographs are taken near the poles of the Galaxy, the number falls off with surprising rapidity. One such shows only about 7,500,000. The first named estimate is probably a safe one.

Star magnitudes and star colors have, in late years, claimed most thorough attention in standard stellar work, because so much in the investigation of vari-

able stars depends on a correct knowledge of magnitudes; and because changes in color suggest possible changes in physical conditions that will be followed with the utmost care. The stellar magnitude of the Sun gives an example of other interesting data of the same kind. It is stated on page 7, that "various estimates of its value have been made ranging from —26 to —27, and it may be taken at about —26.5 (or about 8,954,000,000 times brighter than Sirius)" the most brilliant star in the whole heavens.

In regard to the spectra of the stars Vogel's classification is followed, but in the tables of the few stars given, the parallax and distances are credited to Yale University Observatory. This list embraces such stars as Arcturus, Vega, Capella, Procyon, Altair, α Orionis, Aldebraran, Pollux, α Cygni and Regulus. It does not seem possible that some of the brightest stars in the heavens are so far away that it requires over 300 years for their light to reach us. The author mentions Rigel as such a bright star in Orion on the authority of Sir David Gill. This important fact was generally noticed when it was published by that careful student of stellar parallax.

The absolute size of the stars, their proper motions, and the Sun's motion in space are the remaining topics found in the first chapter. Two interesting conclusions are noticed at its close; one is the close agreement of Professor Campbell's work on the velocity of the Sun through space which gave a result of 12⅛ miles, with that of Professor Kapteyn which came out as 11.44 miles per second. That means that our Sun with all his system of planets moves annually, in space, about four times the Earth's mean distance from the Sun. The other probable fact, still more surprising, if possible, is the work of Eberhard, Keeler and Vogel who found that the great nebula of Orion is receding from the Earth, at the rate of 10.85 miles per second, nearly in the opposite direction from that in which the Sun is moving.

The notice of this first chapter of this book is not presented so fully because it is more worthy than others, but, for the purpose of giving our readers some definite ideas of the general make-up of the work. The second chapter on double, multiple and binary stars is full, apparently exact; and even strong on spectroscopic binaries for so small a book. But the chapter on variable stars is the strongest of all, probably because there is so much of recent knowledge in this new branch of astronomy that to do it justice, nothing less ought to have been done.

The final chapter which is concerned with the Milky Way, the Stellar Universe, and the Nebular Hypothesis is a comparatively brief one consisting of twelve pages. Having been so much interested in these great themes ourselves in recent years, the brief treatment of them here is a little disappointing. Yet not much stress can be justly laid on this, because in this field is the border land of modern study, and much of conjecture prevails in almost everything we know about it.

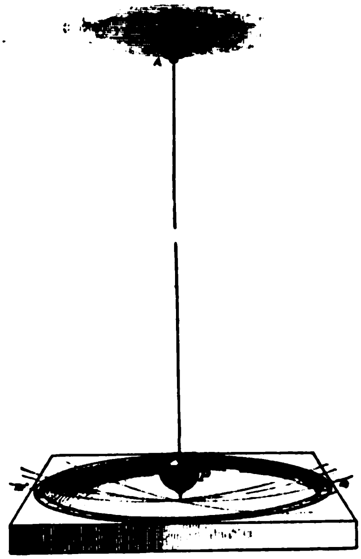
The dozen pages of the appendix and index fittingly closes this volume, that, though unpretentious, fully deserves the favorable notice here given it.

Visible Proof of the Earth's Rotation.—The experiment to which attention is here called usually goes by the name of the Foucault Pendulum Experiment. It is not new, but whenever or wherever tried it always elicits great interest in the minds of the most scholarly, as well as the commonly intelligent

observer who can easily understand its meaning with a brief explanation. We call attention to it now, because we have some things to say about it that may awaken new interest in the experiment if they are not entirely new to all our readers.

This visible proof of the Earth's rotation on its axis was first shown in Paris in 1851, by an ingenious French physicist by the name of Foucault. The Pantheon was the place chosen for the experiment. From the dome of that building, he suspended an iron ball one foot in diameter, by a wire more than two hundred feet long. The ball was drawn to one side and fastened with a cotton cord, and it was held in that position until it came to absolute rest. The cord was burned off and the ball began to swing like a great pendulum and it continued to do so for hours after it was freed.

This same experiment on a small scale was recently tried in the Chapel of Carleton College at Northfield before the Junior class in college astronomy, and some other invited guests. An iron ball weighing one hundred pounds was suspended by a fine piano wire from the ceiling of the Chapel a height of about thirty feet, drawn aside and tied back until it was at rest as above indicated. It was freed by burning the cord and the vibration began in a line almost exactly north and south. The vibrations of this long pendulum were watched for one hour.



Very soon after its swing began it was easily seen that the north end of the vibration turned to the east, and the south end to the west. It seemed to the observers that the direction of the swing of the pendulum was turning around with reference to the floor and the building and the points of compass, and that was exactly the fact. The accompanying illustration makes plain to the eye what is seen generally when the experiment is carefully performed. The right hand side of the cut is south. If the swing of the ball had been kept up continuously for thirty-two hours it would have turned completely around. The above cut is taken from Young's General Astronomy.

If the experiment could be tried at the poles of the Earth, and the plane of the vibration of the pendulum should not change with reference to a star, it is easy to see that the Earth would really turn around under it in just twenty-four hours. For the same reason at the Earth's Equator it would never complete a revolution. If a person could stand at the North Pole and watch such a pendulum for a whole day, the swing of it would seem to be turning around as just described, instead of the motion of the Earth in a contrary direction. What the pendulum appears to do, the Earth really does. It therefore illustrates the real motion of the Earth on its axis very exactly and very satisfactorily. Since there is no turning of the swing of the pendulum at the Equator of the Earth, and a complete rotation at the Poles in twenty-four hours, it is evident that the time of its rotation will increase from the Poles to the Equator, and depend really on the latitude of the place where the experiment is tried. In the latitude of Northfield the time is about thirty-two hours as said above.

The results of this experiment were not entirely satisfactory, because the apparent change in the plane of vibration per hour was too great. In every trial made the same error appeared in the same way with a single exception. The cause of the error was the fact that the ball did not keep its swing constantly in a vertical plane. During the last half hour, it was evident that it was swinging in a long and very narrow ellipse, clockwise, as it should go to increase the angular shift of the vertical plane of motion. It was probably disturbed either by not having come to absolute rest before it was freed, or later by air currents due to the movement of visitors too near to it. The experiment will be tried again with improved suspension apparatus and a magnetic attachment to keep the amplitude of the vibration as nearly a constant quantity as possible, during any length of time desired for the trial. When this very delicate experiment is successfully performed it ought also to show the latitude of the place very closely.

A Novel Observatory.—Herewith we present a cut of a residence with a novel Observatory attached. It is the property of an interested student of astronomy, Mr. C. F. Harms, of Brooklyn, N. Y. From a description, in a private letter, we give the following facts, in his own words, which may interest students of astronomy and be suggestive to amateur observers:

Given a round superstructure (or square or octagonal, for that matter), a revolving dome like mine, of fourteen (14) feet diameter, answering all reasonable demands, can be constructed for about three hundred dollars.

A wooden circular plate, 3″ x 5″, made of 1½″ x 5″ pine sections, doubled and overlapped, is fastened to the studdings of the tower and the outside sheathing boards are nailed to it, so as to project 2″ above the same. This forms a bed for 2½″ x 2″ x ¼″ angle iron, which I had bent in a true circle at a machine shop, and provided with a lot of countersunk holes for fastening with 3″ screws. For convenience of handling, it was made in four pieces, and fitted to a nicety. The 2½″ side forms the base. Another circular wooden plate, about 3″ x 6″ (1″ wider), was provided also with a circle of angle iron, but reversed, the 2½″ side of the iron being fastened to it. This latter wooden circle forms the base for the dome rafters, and the angle irons form the runway for exactly 2″ steel or cast iron balls, on the live ring principle.

A little thought will show that there is no lateral motion to speak of, and if well oiled, the tower works with slight effort. To fill the runway with steel balls, would be quite expensive, as they cost about seven dollars per dozen. I only used

thirty-six (36) of these steel balls, and procured nine dozen glass balls, of ⅛″ less diameter, which latter can be bought for a nominal amount, and distributed them between the steel balls. They tend to prevent them from running together on one side, and answer the purpose very well, absolutely not carrying any weight.

I feel quite proud of my achievement, and if anyone should desire to imitate it, will be pleased to furnish further details which have not been mentioned in this article.

AT SEA GATE, BROOKLYN, N. Y.

I consider this construction far superior to hinged roof arrangements, and certainly of more pleasing aspect, more satisfactory in high winds, more protective against the elements, at about the same cost.

I must add a brief description of my shutter, which also works very satisfactorily. The opening is 2′ 3″ wide, and the shutter rests on a frame similar to a large scuttle of a roof, but with the lower part of cross frame left out. There are a number of so-called sash rollers let in on the longitudinal frame, for it to roll on, and is worked with a small pulley. Two ribs or frames spread about 2″ more than those that the shutter rests on, and also provided with a number of these little rollers, are fastened on the opposite side of the roof, and guide the shutter on its travel. The cross boards of the shutter, overlap 2″ on each side. I hope that I have made this plain enough-

The rafters of the roof, of course, are sections of a true circle, made out of 1¼″ x 4″ pine, doubled and overlapped, and sheathed with narrow ¼″ ceiling boards, laid diagonally on the four quarters of the roof, and the whole is covered with canvas, and well painted. A double thickness of this canvas lapping over the side, nearly touching the tin gutter, forming a perfect protection against rain and snow. The distance from the floor to the opening is six feet. I have room enough to comfortably work with my 8″ equatorial (Henry Fitz lens), of 9′ focus, mounted on iron pillar, to which I have lately attached a driving clock, furnished by Mogey Bros., of Bayonne, N. J., and working very satisfactorily; also find room for a small desk, sextant camera, shelves for books, and other small attachments; a sidereal clock, and a small but exceedingly well constructed transit in the south window.

The room is painted a dead black. The inside of the dome, I have covered with heavy black cardboard, and this offers a tempting surface for decoration with astronomical subjects, on which I am at work at present, drawing them on black cloth with white ink, and pasting them on the cardboard. Beginning at the bottom, the first 3′ 6″ are covered with twelve different aspects of the heavens, for every 2^h of R. A. Above this comes the zodiacal belt, each constellation 3′ x 2′ above which circles the yearly calendar showing the daily position of the Sun. The rest of the space will show the planets in their different orbits, and of proportionate distance and size from the Sun, in the center (apex of the dome). This is commencing to look quite imposing; to me at least.

On the floor of the room, I am trying to locate the noon mark of the Sun daily on a meridian line, the former shining through a good sized pin hole, three feet up on the dome. This is not a success, as far as I can yet see.

BROOKLYN, N. Y., Nov. 5, 1903. C. F. HARMS.

Radium and the Sun's Heat.—In your last week's issue Mr. Hardy directs attention to the fact that no Becquerel rays can be detected from the Sun, and regards this as an objection to the view that the solar heat may be accounted for by the presence of radium.

Let us attempt to calculate the effect to be expected if the Sun's heat were due to this cause.

In doing this, we may assume that the Sun contains 3.6 grams of radium per cubic meter. This was the amount which Mr. W. E. Wilson gave in *Nature* of July 9 as required to emit the observed amount of heat. Experiment shows that when the Becquerel radiation has to pass through lead screens of thickness 1cm. or more, the radiation transmitted is practically all of the γ variety. This is cut down to half its value by 8cm. of aluminium, and in the case of other substances by strata of equal mass per unit area. Now the Earth's atmosphere constitutes a stratum far more absorbent than 1 cm. of lead. We need, therefore, only consider the γ rays, for if these cannot be detected, it is certain that the α and β rays cannot.

For the sake of simplicity of calculation, we shall treat the Sun as a cube, with its side equal to the diameter of the real Sun, and so placed that the normal to one face, which passes through the centre, shall also pass through the Earth. This will be for all practical purposes near enough to the truth.

Let a be the side of the cube, q the quantity of radium per c.c. and λ the coefficient of absorption of the radiation. Then, from an elementary slice, thickness dx, and distance x from the face, the intensity of radiation at a distant point will be

$$a^2qe^{-\lambda x}dx$$

if the radiation due to 1 gram of pure radium at the same (great) distance be taken as unity.

The radiation due to the entire mass will be

$$a^2q\int_0^a e^{-\lambda x}\,dx = a^2q\left[\frac{-e^{-\lambda x}}{\lambda}\right]_0^a = \frac{a^2q}{\lambda}\left(1 - e^{-\lambda a}\right)$$

Now $a = 1.4 \times 10^{11}$ cm.; q, from Mr. Wilson's estimate $= 3.6 \times 10^{-6}$.

Assuming that the coefficient of absorption is proportional to the density and taking the Sun's density as 1/7, and the value of λ for aluminium as 0.086, the value of λ for the Sun comes out 0.0046. Substituting these values, we find that the effect of the Sun is equivalent to that of 1.53×10^{19} grs. of radium at the same distance, assuming this radium to be spread out into a thin layer, so that all the radiation can escape without undergoing absorption in the mass.

Now I have found that the γ radiation from 10 milligrams of radium bromide can barely be detected by the electrical method, where 10 cm. of lead intervene between it and the testing vessel. To decide whether the solar rays would be detectable, we must compare their expected effect after enfeeblement by distance, and by the absorption of the atmosphere, with this.

The distance of the Sun is 1.5×10^{12} times greater than the distance of the radium from the testing apparatus, so that, apart from the atmospheric absorption, the effect of the Sun would be equivalent to that of $\frac{1.5 \times 10^{19}}{(1.5)^2 \times 10^{24}}$, or 67×10^{-6} grams of radium, 10 cm. from the apparatus. This is less than one-thousandth part of the radium used in the experiment cited, and the solar radiation, instead of passing through only 10 cm. of lead, would have to pass through the atmosphere, equal in mass to 32 feet of water, or about 89 cm. of lead. This would, of course, reduce it many million times further. So that, even if all the Sun's heat were due to radium, there does not appear to be the smallest possibility that the Becquerel radiation from it could ever be detected at the Earth's surface.

R. J. STRUTT.

Nature, October 15, 1903.

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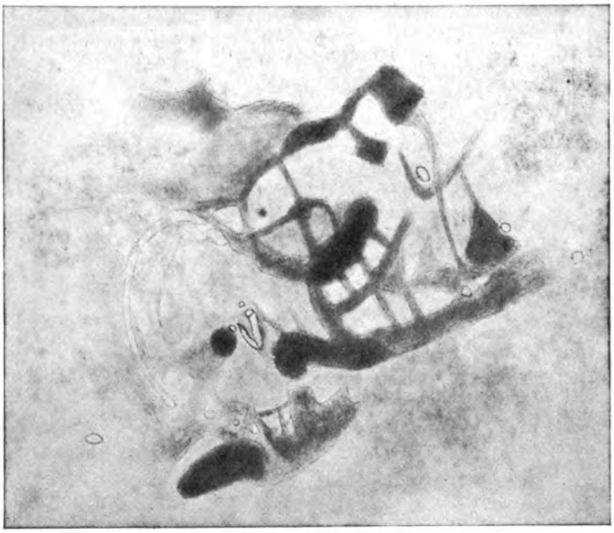
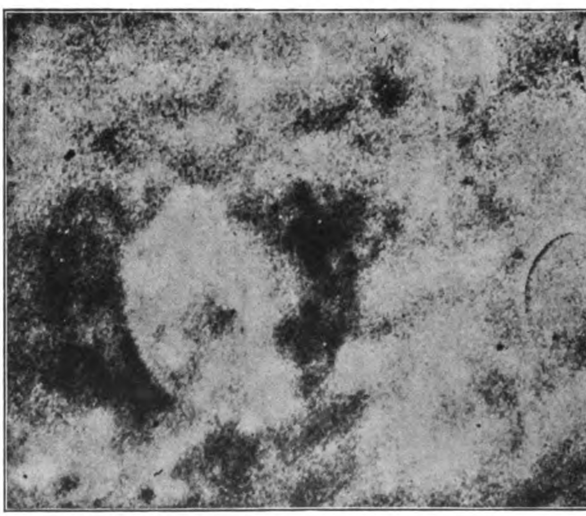
PLATE V





ERATOSTHENES.

Popular Astronomy.

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RECENT STUDIES OF THE MARTIAN AND LUNAR CANALS.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

It has lately been shown by Messrs. Lane, Maunder, and Evans that many of the finer Martian canals are probably non-existent, their appearance being due to certain singular optical illusions. Most of the broader canals however, in the dark regions of the planet, undoubtedly exist, and the same is almost certainly true of some of those in the light regions, such as *Nilosyrtis* and *Nectar*. The chief cause of the illusion seems to be the system of lakes, or oases as they are sometimes called, which were first discovered in large numbers at Arequipa. There is a curious tendency of the human eye to see such dark points united by faint narrow lines, and it has been shown by means of diagrams that these lines sometimes appear when the diagram is at such a distance that the dark dots are themselves invisible. But even without the dots the lines may sometimes appear, joining different portions of the dark regions. We must therefore divide the Martian canals into two classes, those that are genuine and those that are not.

Any canal that appears first as a broad streak of measurable breadth, and then gradually narrows as the season progresses may be classed as genuine, although its image may appear by illusion long after the canal itself has really gone. This narrowing of the canals, especially in the dark regions, is very common after the passage of the vernal equinox on Mars. It is also true of several of the canals in the region about *Solis lacus*. Any canal on the contrary which suddenly appears as a faint narrow line joining two dark regions must in the future be looked upon with suspicion, even if to the trained eye it is fairly well seen. To this class perhaps belong such conspicuous and well known examples as *Phison*, *Gehon* and *Euphrates*, besides very many other less observed canals.

This phenomenon of spurious canals is certainly very singular, but we must be careful that its interest and unexpectedness do not lead us into the error of affirming that because many Martian canals are spurious, therefore all Martian canals are imaginary. It seems indeed a great pity that so much time and energy should have been expended in many observatories in mapping canals in the bright regions of the planet, and comparatively so little time spent on the darker regions, where changes are constantly taking place, and where we should naturally expect the more interesting developments to occur.

Turning now to the other branch of our subject, we find upon the Moon, where the surface conditions are in some respects similar to those upon Mars, although the atmosphere is probably rarer, numerous canals, which on account of their proximity are much more readily studied than the Martian ones. While from the Harvard station in Southern California photographs of Mars were secured showing the *Syitis major*, the *Fastigium Aryn*, and other prominent markings, no one has as yet succeeded in photographing fine enough detail to show a Martian canal. On the Moon, on the other hand, a few canals have already been photographed, both at Arequipa and in Jamaica. Recently a fine photograph has been received through the kindness of Professor Hale, which shows several of the canals to much better advantage than any photograph previously taken. Indeed, it may be said that these latest views taken with the Yerkes telescope show nearly all the detail visible with a 6-inch telescope working under very favorable conditions.

For purposes of comparison, I have placed in the frontispiece a drawing of the canals about Eratosthenes, made in Jamaica, and published in my recent book on the Moon, and an enlargement to the same scale of the same region shown in the Yerkes photograph. The scale is $\frac{1}{2,000,000}$, or about 32 miles to the inch. The drawing was made August 1, 1901, at 8.6 days after sunrise on Eratosthenes, colongitude of the sunrise terminator 116°. It has been impossible to learn the date when the photograph was taken, excepting for the fact that it was taken recently. A comparison with the Harvard photographs shows that its colongitude must be in the vicinity of 140°, which would be about eleven and a half days after sunrise. Whilst therefore the photograph was taken about three days later in the lunation than the drawing, we still find that no very marked changes have occurred in the mean time. Since the drawing was made

only 1.7 days after full moon, when the Sun was nearly in the zenith of the crater, and since the same markings are found on other drawings and photographs made at and before full moon, it will be seen that it is geometrically impossible that these markings should be due to shadows. They represent therefore real differences in surface coloration and nothing else.

We may designate a canal on the drawing by its distance in inches and tenths from the left hand edge and from the bottom of the picture. The V-shaped central peaks are easily recognized in both views, and their inferior size in the drawing shows one of its most obvious defects. The dark canal 1.6, 1.5 in the drawing is very pronounced in the photograph, while the one at right angles to it is well shown. The two other canals centering in the lake 1.5, 1.6 do not quite reach it in the photograph, but appear as one faint, continuous sinuous line. This may be a change, such as frequently occurs upon Mars, and is not necessarily a defect in the drawing. The tendency to draw as straight lines, canals, which are really made up of curves has often been suspected upon Mars. We have a very good illustration of this in the case of the canals to the right of the two bright spots 1.8, 1.3, and 1.9, 1.4. The photograph shows that instead of being straight as drawn, these canals are in reality markedly curved.

The dark spot 1.5, 0.9 appears of quite another shape in the photograph. While in Jamaica it was noticed that this spot was constantly changing its shape, I am not inclined therefore to ascribe this difference in appearance to a defect in the drawing. I am not so sure however regarding the markings just to the right of this spot, which are complicated in structure, and rather difficult to carry in one's mind, while looking back and forth from the telescope to the paper. Some of my other drawings of this region look more like the photograph, and this difference may therefore be due to defective drawing. The fading out of the canal 1.0, 0.9 is well shown in the photograph. A day or two later in the lunation it had entirely disappeared.

Other points of resemblance and of difference in the drawing and photograph might be discussed, but enough have already been shown to prove that lunar photography has at last reached a point where it may be used to check and correct drawings of even the finer detail upon the Moon.

The other photograph is an enlargement from the same original negative to the same scale. The region shown is situated four diameters south, 20° west, from Eratosthenes. The dark region at the top is in fact the site of Gruithuison's celebrated ruined

lunar city. He described a central street from which five or six parallel streets led off on either side at an angle of 45°, like the veins of a leaf. Something of the same sort has been seen by several other observers, and I have myself seen a few of the lines. The so-called streets are apparently a difficult and very curious combination of ridges. What interests us most however, is a series of well marked canals near the center of the view. Just below the center is a white spot. In this is located a Y-shaped combination of canals. From near the foot of the Y a canal leads off to the right, to a very dark spot. This canal is fourteen miles long, and about half a mile in breadth. A short canal branches off from its upper side, i. e., towards the south, and other canals lead off from the dark spot. Below and to the left of this spot is another one of about the same size. Both are suspected of changing the finer details of their shape in the course of the lunation.

In my recent researches I have found, and have endeavored to show, that there is a wealth of fine detail upon the Moon, exhibiting constant variations, of the highest interest to the intelligent selenographer. Of these variations, many it is believed are periodic, while some are wholly irregular in their character. To see them does not involve the use of a large telescope, but it does require a good atmosphere, and also a knowledge of the kind of variations one may expect to observe, and of the sort of places in which they are likely to occur. Without this knowledge much time may be wasted in studying unfavorable localities.

January 4, 1904.

A NEW LIFE OF GALILEO.

HERBERT A. HOWE.

For Popular Astronomy.

In the year 1890 there was published at Florence the first volume of a work entitled "Le Opere di Galileo Galilei-Edizione Nazionale sotto gli auspicii di S. M. il Re d' Italia." Each ensuing year has witnessed the publication of another volume of this monumental work, which is under the editorship of Professor Antonio Favaro of the Royal University of Padua, and which is to be completed in twenty volumes. Upon this Professor Favaro has spent twenty-five years of research. Fortunately for English and American readers he has generously placed all his Galilean studies at the disposal of Mr. J. J. Fahie, so that the latter has

PLATE VI

Region near Eratosthenes.

been enabled to produce a biography of Galileo,* which is by far the most extensive and accurate in our language. It contains many quotations from Galileo's writings, which are of such interest that the readers of POPULAR ASTRONOMY may be glad of the opportunity of perusing a few of them.

1. *The Invention of the Telescope.* In the summer of 1609 a report reached Venice that "a Dutchman had presented to Count Maurice of Nassan a glass by means of which one could see distant things as clearly as if they were near." Galileo, hearing this, began to study over the matter, and succeeded in re-inventing the instrument. The method by which he made the re-invention is set forth in "Il Saggiatore," from which we take the following extract.

"Thus we are certain that the Dutchman, the first inventor of the telescope, was a simple spectacle maker, who, handling by chance different forms of glasses, looked, also by chance, through two of them, one convex and the other concave, held at different distances from the eye; saw and noted the unexpected result; and thus found the instrument. On the other hand, I, on the simple information of the effect obtained, discovered the same instrument, not by chance, but by the way of pure reasoning. Here are the steps: the artifice of the instrument depends either on one glass or on several. It cannot depend on one, for that must be either convex, or concave, or plain. The last form neither augments nor diminishes visible objects; the concave diminishes them, the convex increases them, but both show them blurred and indistinct. Passing then to the combination of two glasses, and knowing that glasses with plain surfaces change nothing, I concluded that the effect could not be produced by combining a plain glass with a convex or a concave one; I was thus left with the two other kinds of glasses, and after a few experiments I saw how the effect sought could be produced. Such was the march of my discovery, in which I was not assisted in any way by the knowledge that the conclusion at which I aimed was a verity.

"But some people believe that the certainty of the result aimed at affords great help in attaining it. Let them read history, and they will find that Archites made a dove that could fly, and that Archimedes made a mirror that burned objects at great distances, and many other admirable machines. Now, by reasoning on these things such people, doubtless, will be able, with very little

* Galileo, His Life and Work, by J. J. Fahie; published by James Pott & Co.; $5.00.

trouble, and with great honor and advantage, to tell us how they were constructed. And even if they do not succeed they will be able to certify for their own satisfaction that that ease of fabrication which they had promised themselves from the foreknowledge of the result is very much less than what they had imagined."

2. *The Bigotry of Professed Men of Science.* It is well known that the discoveries made by Galileo with his "optic tube" did not meet with immediate favor in the minds of most of the distinguished occupants of the professorial chairs of the foremost universities of Europe.

Clavio, of Rome, a mathematician of considerable repute, scoffed at the idea that Jupiter had four moons, and intimated that Galileo had put artificial satellites inside of his telescope. In reply Galileo offered 10,000 scudi to any one who would accomplish such a mechanical and optical feat. Of this mathematician, and others of like ilk Galileo wrote to Kepler under date of Aug. 19, 1610, as follows:

"What do you say of the leading philosophers here to whom I have offered a thousand times of my own accord to show my studies, but who, with the lazy obstinacy of a serpent who has eaten his fill, have never consented to look at the planets, the Moon, or telescope? Verily, just as serpents close their ears, so do men close their eyes to the light of truth. To such people philosophy is a kind of book, like the Æneid or Odyssey, where the truth is to be sought, not in the universe or in nature, but (I use their own words) by comparing texts! How you would laugh if you heard what things the first philosopher of the faculty at Pisa brought against me in the presence of the Grand Duke. He tried hard with logical arguments, as if with magical incantations, to tear down and argue the new planets out of heaven!"

As a specimen of the logic with which the opponents of Galileo tried to overwhelm him we quote from the *Dianoia Astronomica* of Francesco Sizzi, an astronomer of Florence:

"Moreover, these satellites of Jupiter are invisible to the naked eye, and therefore can exercise no influence on the Earth, and therefore would be useless, and therefore do not exist. Besides, the Jews, and other ancient nations, as well as modern Europeans, have adopted the division of the week into seven days, and have named them after the seven planets. Now if we increase the number of the planets, this whole and beautiful system falls to the ground."

3. *The Rings of Saturn.* At first Galileo saw this planet as a

triple object consisting of one central body flanked by two smaller ones, which gradually diminished and finally vanished, to his great amazement and confusion. Arago concluded that Galileo was so disheartened by this phenomenon that he did not observe the planet further. But this conclusion is wide of the truth. Not only did Galileo see the two attendants of Saturn reappear, but he even drew pictures which plainly show that he noticed the dark space between the ball and what we now know to be the rings. In looking at the facsimiles of some of these sketches in Mr. Fahie's book one is astonished that Galileo did not discover that a ring surrounded the central ball. Professor Favaro has found in the Ambrosian Library at Milan a letter written to Prince Cesi by Galileo, in which occurs the following passage:

"I cannot rest without signifying to your Excellency a new and most strange phenomenon observed by me in the last few days in Saturn. Its two companions are no longer two small and perfectly round globes, as they have hitherto appeared to be, but are now bodies much larger, and of a form no longer round, but as shown in the annexed figure, with the two middle parts obscured, that is to say, two very dark triangular-like spaces in the middle of the figure and contiguous to the middle of Saturn's globe, which latter is seen, as always, perfectly round."

Twenty-four years afterward, when Galileo had been blind for three years, he summed up his observations of Saturn in the language below:

"When first I observed Saturn he was composed of three round stars, situated in a straight line from *Ponente* to *Levante*, of which the central was much larger than the lateral ones. Thus I continued to see him for some months. Then, after an interval of some more months, I again examined him and found him solitary, i. e. the great central star was only to be seen. Amazed at this result, and supposing it to be due to some kind of change, I ventured to say that in five or six months, i. e. at the summer solstice, the two small lateral stars would reappear. They did, and so I saw them for a long time after. Then after another interval, during which Saturn was masked by the Sun's rays, I again observed him, and now saw him with two mitres, instead of round stars, which gave him the figure of an olive. I saw the central globe very distinctly, and two very dark spots in the middle of the attachment of the mitres, or, as one may say, the ears. So I observed him for many years; and now your Reverence writes (as also other of my friends) that the mitres are transformed into two small globes. It may be that in the last three

years, during which I have been unable to make any observations, Saturn may have become once again solitary, and then later on may have returned to the form in which I at first observed him. It will be for the future and for others to make observations, registering the times of mutation so as to accurately determine their periods—that is, if there will be any persons curious enough to do what I, from the same motive (not knowing how to do better), have done for so long a time."

4. *The Bible and Science.* One day in December, 1613, there was a dinner party at Pisa, and the Professor of Physics in the University of that city, in a conversation with the Dowager Duchess of the Tuscan Court, assured her that the doctrine of the double motion of the Earth, which was powerfully reinforced by Galileo's discoveries, was contrary to Scripture. Castelli, the Professor of Mathematics in the same University, was called in to defend Galileo, and afterwards apprised the latter of the discussion. In a few days Galileo wrote to Castelli a letter setting forth his views of the relation between Scripture and Science. This letter, which was indiscreetly published by Castelli, hastened the coming of the day when Galileo was brought to an accounting for his supposed heresies. Mr. Fahie gives the following quotation from this letter:

"As the Bible, although dictated by the Holy Spirit, admits (for the reasons given above) in many passsages of an interpretation other than the literal one, and as, moreover, we cannot maintain with certainty that *all* interpreters are inspired by God, I think it would be the part of wisdom not to allow any one to apply passages of Scripture in such a way as to force them to support as true any conclusions concerning nature, the contrary of which may afterwards be revealed by the evidence of our senses, or by actual demonstration. Who. will set bounds to man's understanding? Who can assure us that everything that can be known in the world is known already? * * * I am inclined to think that Holy Scripture is intended to convince men of those truths which are necessary for their salvation, and which being far above man's understanding cannot be made credible by any learning, or by any other means than revelation. But that the same God who has endowed us with senses, reason, and understanding, does not permit us to use them, and desires to acquaint us in another way with such knowledge as we are in a position to acquire for ourselves by means of those faculties—*that*, it seems to me I am not bound to believe, especially concerning those sciences about which the Holy Scriptures contain only small frag-

ments and varying explanations; and this is precisely the case with astronomy, of which there is so little that the planets are not all enumerated, only the Sun and Moon, and once or twice Venvs under the name of Lucifer. This, therefore, being granted, I think that in discussing natural phenomena we ought not to begin with texts from Scripture, but with experiment and demonstration, for from the Divine Word Scripture and Nature do alike proceed. And I can see that that which experience sets before our eyes concerning natural effects, or which demonstration proves unto us, ought not upon any account to be called in question, much less condemned, upon the testimony of Scriptural texts, which may (under their mere words) have meanings of a contrary nature."

5. *Experiment contrasted with Logic.* In the year 1619 appeared a pamphlet in abuse of Galileo's views; it was written by Grassi, a Jesuit Father, under the pseudonym of Lotario Sarsi. In this pamphlet Grassi had used as an argument in behalf of his own views a ridiculous story about the Babylonians. With keen irony Galileo replied as follows:

"If Sarsi insists that I must believe, on Suidas's credit, that the Babylonians cooked eggs by swiftly whirling them in a sling, I will believe it; but I must say, that the cause of such an effect is very remote from that to which it is attributed, and to find the true cause I shall reason thus: If an effect does not follow with us which followed with others at another time, it is because, in our experiment, something is wanting which was the cause of the former success; and if only one thing is wanting to us, that one thing is the true cause. Now we have eggs, and slings, and strong men to whirl them, and yet they will not become cooked; nay, if they were hot at first they more quickly become cold; and since nothing is wanting to us but to be Babylonians, it follows that being Babylonians is the true cause why the eggs became cooked, and not the friction of the air, which is what I wish to prove. Is it possible that in traveling by post, Sarsi has never noticed what freshness is occasioned on the face by the continual change of air? And if he has felt it, will he rather trust the relation by others of what was done two thousand years ago at Babylon, than what he can at this moment verify in his own person? I, at least, will not be so wilfully wrong, and so ungrateful to nature and to God, that having been gifted with sense and language I should voluntarily set less value on such great endowments than on the fallacies of a fellow-man, and blindly and blunderingly believe whatever I hear, and barter the freedom of my

intellect for slavery to one as liable to error as myself."

6. *The Manipulation of a Microscope.* In 1612 Galileo presented a microscope to the King of Poland. Two years later the Canon of the Cathedral of Sarlat visited the great philosopher; of this visit he said:

"Galileo told me that the tube of a telescope for observing the stars is no more than 2 feet in length; but to see well objects, which are very near, and which on account of their small size are hardly visible to the naked eye, the tube must have two or three lengths. He tells me that with this long tube he has seen flies which look as big as a lamb, are covered all over with hair, and have very pointed nails, by means of which they keep themselves up and walk on glass, although hanging feet upwards, by inserting the points of their nails in the pores of the glass."

In 1624 Galileo sent a microscope to Prince Cesi, with the following explanation of the method of using it:

"I send your Excellency a little spy-glass for observing at close quarters the smallest objects, which I hope will afford you the same interest and pleasure that it does to myself. I delayed sending it because my first specimens were imperfect by reason of the difficulty in fashioning the lenses. The object is placed on a movable circle (at the base of the instrument) which can be turned in such a way as to show successive portions, a single pose being unable to show more than a small part of the whole. As the distance between the lens and the object must be precisely adjusted in order to see things that are in relief, it is necessary to bring the glass nearer to and farther from the object, according to the parts to be examined. Therefore the little tube is made adjustable on its stand or guide. The instrument should be used in a strong light, or even in full sunlight, so as to illuminate the object as much as possible.

"I have examined with the greatest delight a large number of animals, amongst which the bug is most horrible, the gnat and the moth very beautiful. I have also been able to discover how the fly and other little animals are able to walk on window-panes and ceilings feet upwards. But your Excellency will now have the opportunity of observing thousands of other details of the most curious kind, of which I shall be glad to have an account. In short one may contemplate endlessly the grandeur of Nature, how subtilely she works, and with what unspeakable diligence.

"P. S.—The little tube is in two pieces, so that you may lengthen it or shorten it at pleasure."

It is evident that if Galileo could step into a modern biological

laboratory he would at once be at home with a compound microscope.

7. *Galileo's daughter, Maria Celeste.* The picture of the later years of Galileo's life is a very sombre one, because of his sufferings from disease and persecution. His hours of pain and gloom were blessed by the loving devotion of his eldest daughter, the nun Maria Celeste, whose correspondence with her father was carefully preserved by him, and evinced her love and care in a striking manner. The other nuns might have their patron saints, in whom they confided. But the name of her patron saint was not found in any Calendar of the Church: she was a "*Devoto*" of her own father, and he of her. Her piety and devotion are well set forth in a letter written at a time when she thought him in danger from a virulent plague which was rife within the city.

"I believe that you have by you all the remedies and preventives that are required, so I will not repeat. Yet I would entreat you, with all reverence and confidence, to procure one more remedy—the best of all, to wit, the grace of God, by means of true contrition and penitence. This is without doubt the most efficacious remedy both for soul and body. For, if in order to avoid this sickness it is necessary to be always of good cheer, what greater joy can we have in this world than the possession of a good and serene conscience? * * * I pray your Lordship to accept these few words prompted by the deepest affection.

"I wish also to acquaint you with the frame of mind in which I find myself at present. I am desirous of passing away to the next life, for every day I see more clearly the vanity and misery of this present one. There I would hope that my prayers for your Lordship would have greater efficacy."

8. *Galileo before the Inquisition.* So much has been written on this subject by the friends and by the foes of the Roman Church that it seems quite difficult to form a just opinion concerning many of the details of the matter. Though Mr. Fahie evidently sympathizes with Galileo in the sore trials to which he was subjected in the course of his long and painful conflict with the ecclesiastical authorities, he has endeavored to look at both sides of the affair, and to put a fair interpretation upon the evidence in hand. The sentence of the Inquisition,—read to Galileo on June 22, 1633 in the presence of a large assembly of cardinals and prelates—is given in full and covers several pages. The burden of it is that Galileo was ordered nearly twenty years before to abstain from holding and teaching the false doctrine of the double motion of the Earth, and that he had disobeyed these

orders. In consequence of this disobedience the following sentence was passed upon him:

* * * "Invoking, therefore, the most holy name of our Lord Jesus Christ, and of His Most Glorious Virgin Mother, Mary, We pronounce this Our final sentence, which, sitting in council and judgment with the Reverend Masters of Sacred Theology and Doctors of both Laws, Our Assessors, We put forth in this writing in regard to the matters and controversies between the Magnificent Carlo Sincero, Doctor of both Laws, Fiscal Proctor of the Holy Office, of the one part, and you, Galileo Galilei, defendant, tried and confessed as above, of the other part, We pronounce, judge, and declare, that you, the said Galileo, by reason of these things which have been detailed in the course of this writing, and which, as above, you have confessed, have rendered yourself vehemently suspected by this Holy Office of heresy, that is of having believed and held the doctrine (which is false and contrary to the Holy and Divine Scriptures), that the Sun is the center of the world, and that it does not move from east to west, and that the Earth does move, and is not the center of the world; also, that an opinion can be held and supported as probable, after it has been declared and finally decreed contrary to the Holy Scripture, and, consequently, that you have incurred all the censures and penalties enjoined and promulgated in the sacred canons and other general and particular constitutions against delinquents of this description. From which it is Our pleasure that you be absolved, provided that with a sincere heart and unfeigned faith, in Our presence, you abjure, curse, and detest, the said errors and heresies. and every other error and heresy, contrary to the Catholic and Apostolic Church of Rome, in the form now shown to you.

"But that your grievous and pernicious error and transgression may not go altogether unpunished, and that you may be made more cautious in future, and may be a warning to others to abstain from delinquencies of this sort, We decree that the book 'Declogues of Galileo Galilei' be prohibited by a public edict, and We condemn you to the formal prison of this Holy Office for a period determinable at Our pleasure; and by way of salutary penance, We order you during the next three years to recite, once a week, the seven penitential psalms, reserving to Ourselves the power of moderating, commuting, or taking off, the whole or part of the said punishment or penance." * * *

After the sentence had been pronounced Galileo was compelled to kneel before the assembled company, and to make a complete

and humiliating abjuration, The decree of 1616 prohibiting all books which teach the Copernican doctrine stood until 1822, when it was resolved "that the printing and publication of works treating of the motion of the Earth and the stability of the Sun, in accordance with the opinion of modern astronomers, is permitted in Rome." Not till 1835 was Galileo's name removed from the Index Expurgatorius.

Mr. Fahie holds the view that Galileo was not subjected to the torture of the rack, and was not thrown into a dungeon of the Inquisition; also that the story that he altered the words "Eppur si muove" at the conclusion of his abjuration is utterly improbable. Galileo expressed an opinion as to the cause of his troubles with the Church in a letter to Diodati, written about a year after his abjuration.

"Thus, about two months ago when a dear friend of mine at Rome was speaking of my affairs to Father Cristoforo Griemberger, mathematician at the *Collegio Romano*, this Jesuit uttered the following precise words: 'If Galileo had only known how to retain the favor of the fathers of this college he would have stood in renown before the world, he would have been spared all his misfortunes, and could have written all he pleased about everything—even about the motion of the Earth.' * * * A certain Jesuit father has printed at Rome that the opinion of the motion of the Earth is of all heresies the most abominable, the most pernicious, the most scandalous; and that one may maintain in professorial chairs, in society, in public discussions, and in books, any and every argument against the principal articles of faith, against the immortality of the soul, against the creation, against the Incarnation, against everything. with one exception only—the dogma of the immobility of the Earth!"

CHAMBERLIN OBSERVATORY,
University of Denver.

RECENT ASTRONOMICAL RESEARCH.

WM. W. PAYNE.

It is our aim, each month, in a general way, to call attention very briefly to some of the more prominent lines of original astronomical work, in regard to plans, methods or results, or, in any other respect, which may seem to be very useful to those interested in astronomy. Photography has come into such general use in some branches of the science, that we now wonder that

this very efficient aid in astronomical research had not been put in place of service long ago. The great star charts of the heavens, the observations of Eros, the work on nebulæ and comets are some of the important lines of work in which photography works especially well.

Harvard College Observatory in Cambridge and at its station in Peru has done, in the last few years, a vast amount of astronomical work by the aid of photography chiefly. In Professor E. C. Pickering's last report is found a brief statement in this regard that is well worth copying, for the general reader. It is as follows:

"The problem of obtaining the greatest return for astronomical science from a given expenditure of money should be the principal concern of every astronomer. 'It is obvions that no single observatory can accomplish as much and as good work as could be done through the efforts of the entire astronomical world. The recent attempt on the part of this Observatory to secure an endowment for international astronomical research has led certain persons to infer that the present needs at Harvard are supplied. An important part of this very plan is to enable a large Observatory like this, which can undertake to great advantage large pieces of routine investigation quite beyond the reach of the smaller observatories, to use its resources to the best advantage. It can coöperate with others, and thus bring the energy of many minds to bear upon a single problem. As an illustration, it is recognized that the distribution of the stars in space is one of the most important problems in astronomy. This investigation depends on the accurate measures of the light of stars in all parts of the sky. But little work of this kind has been done on the light of the southern stars. Especial attention has been paid to photometry at this Observatory, and we have an excellent southern station where such work could be carried on to great advantage. An expenditure of one thousand dollars annually for five years would go far to provide for this want; but as the expenses here for the last year have exceeded the income, additional work cannot be undertaken. Again, the Harvard collection of astronomical photographs gives the history of the stellar universe for the last fourteen years with a completeness not attempted elsewhere; but these photographs are of little use unless a careful study is made of them. A satisfactory plan has been prepared for organizing a corps of observers at a cost of about five thousand dollars a year, for studying these photographs. The Carnegie Institution appropriated $2,500 last year for this work,

but gave no assurance that it would be increased, or even continued. Results have already been obtained which show what might be expected from a permanent maintenance of this work; but if the appropriation is not continued much work will be lost, and may assistants who have been carefully trained will be obliged to seek work elsewhere. The great increase in the resources of the Observatory has not been accompanied by a similar increase in the amount of capital available for plant. Accordingly, the buildings and instruments here, purchased mainly from income, are very inferior to those of other observatories whose endowment is much less. The anonymous gift of 1902 has been of the greatest service in this respect, since it will provide two reflectors of twenty-five inches aperture, one for use on the northern, and the other on the southern stars, and has given us a fireproof wing to the building already used for storing and studying the photographs. The cost of the entire building and wing was only about $20,000, and two similar buildings would provide for a much needed new library for the Observatory, computing rooms, photographic laboratory, and a workshop. All of this work is now carried on in very inferior wooden buildings, some of them more than half a century old. Much money is also spent in strengthening floors and repairing foundations; and the danger from fire is ever present.

If the sum of $50,000 could be expended during the next ten years for such researches and buildings as those mentioned above, it is believed that a relatively large return in scientific results would be obtained. Our expenses now slightly exceed our income, and if they are cut down, a proportionately greater diminution in work will ensue. An unrestricted fund like that mentioned above would permit our present appliances to be used to the best advantage. Whatever may be the future of the Observatory, there is no doubt that a reasonable sum could be wisely expended at once, while a delay of several years may bring other conditions less favorable to effective expenditure, and will certainly cause some needs to be neglected which now seem most urgent."

Another piece of excellent photographic work is found in the new book prepared by Professor William H. Pickering of Harvard College Observatory, titled, The Moon. This volume is a summary of the existing knowledge of our satellite with a complete photographic atlas; it is published by Doubleday, Page and Company of New York, the net price being ten dollars. The description of this book consists of thirteen chapters, embracing

103 pages, large size, with wide margin; very fully illustrated with drawings and half-tone cuts, interspersed in the reading matter.

In the text the author considers the origin of the Moon; its rotation, distance, orbit, light, libration gravitation; atmosphere, water, temperature; origin of the lunar craters; illustrative artificial craters; origin of the various formations; active lunar craters, river-beds; ice on the Moon, the bright streaks; vegetation, the lunar canals; recent investigations; fancies, apparent size, suppositions, influence on the weather; history of lunar research; the photographic atlas, the map of the Moon, and lunar altitudes.

In his treatment of these themes, the author has passed by almost all the common-place information found in the ordinary text-books of astronomy, and has presented the latest phases of study known to the modern selenographer in plain and untechnical language. This fact alone makes the book a very useful one for the popular reader, the student and the professional scientist as well.

It may be known to some of our readers that the author of this new volume recently had charge of a party from Harvard College Observatory which went to Jamaica, and there made a very complete and valuable set of Moon photographs. These have been related and arranged to form the atlas before referred to. In planning how to take the photographs, it was decided to divide the diameter of the Moon, east and west, into eight equal parts and erect perpendiculars at the dividing points which gave in all sixteen regions. Of each of these divisions five photographs were taken, making eighty in all, which covered the entire, visible surface of the Moon five times. The views for each region are, one at lunar sunrise, one two days after sunrise, one at lunar noon; another two days before lunar sunset and the last at lunar sunset. The manifest advantage of this plan is, that it shows the same objects on the Moon's surface, at least, under five different phases of illumination, to say nothing about some of the overlapping parts of the plates which appear as many as ten times in the series. This fact suggests a pretty severe test on the skill of the artist to get all parts of these Moon pictures so well in the focus of his instrument that one does not notice obtrusive lack of definition in any. It appears to the writer that not all the pictures are equally sharp or equally good; but the wonder is that there are not greater differences in merit among so many taken within a period of seven months.

In these photographs the author has also avoided a fault which appears in so many pictures of the Moon which have been greatly enlarged from the original negatives. Sometimes this work of enlargement has been carried so far as to make the granular structure of the film of the original negative stand out harshly even in the finest prints that can be made. Such a glare is unnatural and is always disappointing to those who rightly expect the soft, continuous finish of a photographic film that will differentiate, in detail, most beautifully and almost perfectly, when it is not overworked.

The appearance is that these good results could not have been realized without an instrument giving a wide, flat, photographic field, and it is interesting to know how this end was accomplished. From the descriptive part of the photographic atlas it is learned that a twelve-inch objective with a photographic focus of 135 feet and 4 inches was mounted on the side of a hill with inclination of about 30°. The upper end of this long tube came into a second story of a building where the observations were made. At the lower end of it was the objective and a mirror 18 inches in diameter, used as a reflector to throw the light of the Moon through the objective and the long tube to its eye-end. By means of electric motors the mirror and the plate-holder were made to revolve, so as to neutralize the rotation of the Earth on its axis. It is said, by the author, that this novel means of controlling the mirror and the photographic plate, in actual use, worked very well. A good objective of this kind, handled in this way, ought to do fine work.

As an illustration of how the photographs were prepared for the atlas, we will cite one instance which was the first step in constructing the author's map of the Moon. The negative of the full Moon finally chosen was taken, at Jamaica, on the night of Aug. 29, 1901 16^h 50^m G. M. T. The image measured 15.7 inches in diameter

It was enlarged on bromide paper to a diameter of about 27.7 inches. The craters, parallels and meridians were then inserted. When completed the map was reduced by photography to an approximate diameter of 13.7 inches, which is just one ten-millionth of the diameter of the Moon. This would give a scale, measured on the Moon's axis of about 160 miles to the inch.

It would be profitable to our readers to take up the themes presented by the author in this new book, and give somewhat in detail the new things therein said in connection with each, but this would carry us too far from the object of this already extended

notice of this popular work. It will suffice to say that Professor W. H. Pickering has made a most valuable and timely contribution to the literature of the Moon, by the aid of the best modern methods of research. The fact that the book has been written entirely in popular language is one of the best things about it. Intelligent popular readers will find it the best reference book for late knowledge of the Moon in connection with any good text-book on the subject that we know of.

The author calls our attention to the following errata:

Page 32, line 31, for 5.7 read 5.6. Page 37, line 18, for (64,159) read (2.5, 6.3). Page 37, line 25, Plate 3B is inverted. These measures should therefore be made from the left and top. Page 37, line 29, for 6.3 read 6.2. Page 37, line 31, for 6.6 read 6.5. Page 39, line 5, for 4.1 read 4.2. Page 43, line 16, for 8 read δ. Page 49, line 19, for B read C. Page 49, line 25, for Messier, A read Messier A. Page 52, line 2, see page 37, line 25, above. Plate F. The straight dark lines on Figures 6 and 7 are defects. Figure 7 should be turned one-quarter way round, so as to resemble Figure 8. Page 68, line 18, for 33, read 13. Page 70, line 27, for 3B (1.2, 8.5) and 3E (1.1, 8.6) read 2A (3.2, 1 2) and 2C (3.2, 1.8). Page 70, line 28, for 5 and 8 read 3 and 6. Plate H, last line, for 22 read 2. Page 103, line 1, for contents read constants. Plate 3B. This plate is inverted.

JESUIT ASTRONOMY.* II.

JOHN SCHREIBER, S. J.†

FOR POPULAR ASTRONOMY.

Observations.

If we ask what the Jesuits have observed, the self-evident answer is: Very much. This is warranted by the many publications in which the current observations are communicated. Thus, for example, Fr. Maximilian Hell in Vienna edited the ephemerides from 1757 until 1795, and Fr. Triesnecker from 1794 until 1806. These, besides the numerical which is the essential, but at the same time the most laborious part of the ephemerides, alway contain an appendix of the observations made in the course of the year. Besides these Hell also issued about thirty separate publications, Triesnecker 7.—The like is true of Fr. Francis Weiss in Tyrnau, who published the observations from

* Continued from page 20.

† "Die Jesuiten des 17. und 18. Jahrhunderts und ihr Verhältnis zur Astronomie" by Johann Schreiber, S. J., Assistant Astronomer at the Haynald Observatory, Kalocsa, Hungary. *Natur* und *Offenbarung*, Vol. 49, 1903.—Translated by William F. Rigge, S. J., Creighton University Observatory, Omaha, Neb.

1756 to 1770; the last years being by Fr. Francis Taucher. For the rest a glance at Riccioli's Almagest is sufficient to show what a busy life the Jesuit astronomers lived. Where he speaks of eclipses, for instance, he mentions very many Jesuits who took part in the observations, and gives the manner of observing used by each and the result. In order to give prominence to only one eclipse: for the lunar eclipse of April 14, 1642, he mentions the following places (I omit the names and remarks): Mantua, Trieste, Bologna, Paris, Cologne, Paderborn, Würzburg, Ingolstadt, Eichstädt, Prague, Glatz, Neisse, Canada.—The eclipse of November 8, 1612, is also interesting. It was observed by Blessed Charles Spinola at Nangasacki; Fr. Julius de Alenis at Macao, Fr. Uremanns at the same place, Fr. Scheiner in Ingolstadt.

The transit of Venus of 1761 was observed* at Vienna by Fathers Hell, Liesganig, Steinkellner, Mastalier and Richtenburg, at Madrid by Fr. Rieger and others, at Florence by Fr. Ximenes, at Ingolstadt by Fr. Kratz, at Würzburg by Fr. Huberti and others, at Schwetzingen by Fr. Mayr, at Dillingen by Fr. Hauser, at Laibach by Fr. Schöttl, at Tyrnau by Fr. Weiss.

These current observations, however, are just the business of every observatory and of every astronomer.—I will therefore give prominence only to those observations which were either very excellent or the first to be instituted in any one direction, or otherwise very remarkable, and in their enumeration I will keep to the customary classification of the Sun, the Moon, and the Stars.

The Sun.

To begin with the Sun, the first place not only among Jesuit astronomers, but among all old astronomers, is due to Fr. Christopher Scheiner. I say the first place, because he was by all odds the first to occupy himself thoroughly for many years with the Sun; because he was the first to arrive at results which have value even today, and of which it is not at all certain that they have really been improved upon.

Fr. Christopher Scheiner (born in Suabia 1573, died in Neisse 1650) had already in presence of his pupil Cysatus discovered sun-spots in March, 1611, and from that time on had observed them uninterruptedly, and indeed in order to make sure of the matter, had organized a whole corps of solar observers, all Jesuits, to observe simultaneously with himself: Fr. J. B. Cysatus

* De Backer.—Title "Hell." [*Cfr. Astr. Papers of Amer. Ephem.* Vol. II.]

in Ingolstadt and afterwards also in other places, Fr. Chrysostom Gall in Lisbon, Fr. George Schönberger in Freiberg, Fr. Joseph Biancani in Parma, Fr. Caspar Ruess in the West Indies, Fr. Charles Malapertius in Belgium, and others. In the year 1631 he published his great work under the title Rosa Ursina, in which his observations are given and illustrated with very good drawings. The principal result of his researches is the determination of the elements of the Sun's rotation, that is, the inclination of the axis toward the ecliptic, the longitude of the ascending node and the time of rotation, performances which are indeed duly acknowledged in almost all astronomical text books. But the rest of the contents of the great folio volume is less known—and it is not less interesting. It is to be remarked that the telescope was invented in 1608 and that the tube with which Scheiner made his last observations, in about 1625, could not have been an excellent instrument, as well on account of lack of achromatism, as certainly also on account of want of proper polish and the smallness of the objective. At all events Scheiner is none the worse for his instrument, speaks often of its extraordinary performing power—because he happened to know nothing better. The principal reason of his seeing so much and such delicate things, that one is forced to wonder at it, must probably have been due to his skill, since he adopted various ways to protect himself against delusion and to insure the true facts of his observations.—Thus he was the first to apply the so-called dark glasses that are now used generally, and the first to invent the artifice of diaphragming the objective. In short, in the handling of the telescope he was perfectly at home, even the distortion caused by the objective did not escape him when he projected the Sun's image upon paper, which was his usual method of observing.

Now, Scheiner has established so many and such delicate facts with this telescope, that we can boldly maintain that, except for spectroscopy and photography, solar researches have not yielded anything new that is not already to be found in Scheiner's observations, as the astronomer Winecke declares* when he says: "In his Rosa Ursina truths are established that have been forgotten because the earlier observer was wantonly set aside, and the same had to be discovered anew not long ago." In order then briefly to indicate the most important things, the granulation was already known to him, no less than the veiled spots; although he does not use the word, which they did not yet

* Vierteljahresschrift d. Astr. Ges. 1878.

exist, his description of these phenomena is so clear and unmistakable that no doubt is possible about the matter. He has very thoroughly examined the formation and dissolution of the spots; and he treats in a masterly way the question which even today is much discussed, whether the spots are depressions. He proves himself possessed of a knowledge which was very advanced for that time, inasmuch as he establishes the proper motion of the spots in longitude and latitude, no less than the frequently eccentric position of the penumbra, and the more exuberant and solid development of the spots and faculæ at the Sun's preceding limb. The word faculæ comes from him. He had formed ideas about the physical constitution of the Sun very like those of today, and he even surmised the interior of the Sun, the nucleus or kernel, to have a rotational velocity different from that of the outer shell.*

The Moon.

The Moon was studied in a thorough manner by Fathers J. B. Riccioli and Fr. M. Grimaldi,—or as v. Littrow in his "Wunder des Himmels" expresses himself in a somewhat queer fashion, "the well known Jesuit Riccioli has occupied himself very much with the Moon and with the whole of astronomy generally, without, however, thereby advancing this science very much." We shall see later that this view is not shared by others. I have shown elsewhere† that v. Littrow's notice, which begins with the above words, and with which he makes fun of Riccioli's lunar nomenclature, is false in all its details and only proves that v. Littrow was very poorly informed in lunar affairs. Now, Riccioli has introduced the lunar nomenclature which is in use even today, and in a very systematic, but hitherto entirely overlooked manner, has very much lessened the labor of the memory in locating the lunar formations. But his colaborer Grimaldi drew up one of the first maps of the Moon worthy of the name. The first was the map of Langren of 1645, then the one of John Hevelius followed in 1647. In the year 1651 Fr. Riccioli published in his "Almagest" the map of the Moon that Grimaldi had designed and drawn from his own observations. Edmund Neison, the renowned lunar topographist of the present day, makes the

* [For further information the reader is referred to "P. Christoph Scheiner, S. J. und seine Sonnenbeobachtungen" by the same author, *Natur* und *Offenbarung*, Vol. 48.]

† Die Mondnomenklatur Riccioli's und die Grimaldische Mondkarte, Stimmen aus Maria-Laach. Freiburg i. Br. 1898, Pamphlet 3.

following remark about this map.* "Riccioli, although an inferior observer to Hevelius, has had the merits of his map much underestimated; for it appears to have been the result of good lunar observations, and is in some particulars superior in completeness and accuracy even to Hevelius's, though from his less exact estimates of distances it is less so on the whole. But his labors have afforded results far superior to what would have been expected from the disparaging observations of Beer and Mädler. In his remarks as to the probable nature of the surface Riccioli is juster than most of his immediate successors." Riccioli and Grimaldi have in addition occupied themselves much with observations of the libration, so that Riccioli himself says that Grimaldi's observations of the libration, when gathered together, would make a good-sized book. Both carried on a lively expistolary correspondence with Hevelius.

The Stars.

In the realm of the stars also the Jesuits have done some meritorious work.—To begin with the planets, it is to be noted that Fr. John B. Zupi was the first to discover the dark stripes or bands that are to be found on Jupiter. In regard to Saturn (already before Huygen's time) a determination of Grimaldi's† which gave Saturn the nearly correct oblateness of 1-12 was about the only certain result. The phases of Mercury, which Galileo surmised more than saw, were first seen by Fr. John B. Zupus in Naples on May 23, 1639, and repeatedly afterwards; he also furnished accurate drawings.

An epoch-making discovery in the domain of the fixed stars, which was at first misunderstood, but which continually found more recognition, is due to Fr. Christian Mayer, astronomer at the Mannheim observatory. Humboldt pronounces in a very acceptable way about it‡: "Christian Mayer, the Mannheim astronomer, has the great merit of having first (1778) made the fixed stars a special object of research, by the sure method of actual observations. The unfortunate choice of the term *satellites of the fixed stars,* * * * exposed him to bitter attacks from his contemporaries * * * That dark planetary bodies should become visible by reflected light, at such an immense distance, was certainly improbable. No value was set upon the results of his carefully conducted observations, because

* Neison, The Moon, London, 1876, p. 87.

† Wolf, Handbuch II, 470.

‡ Humboldt, Cosmos, Otté's translation, London 1851, vol. 3, p. 275.

his theory of the phenomena was rejected; and yet Christian Mayer, in his rejoinder to the attack of Father Maximilian Hell, Director of the Imperial Observatory at Vienna, expressly asserts "that the smaller stars, which are so near the larger, are either illuminated, naturally dark planets, or that both of these cosmical bodies—the principal star and its companion*—are self luminous Suns revolving round each other." The importance of Christian Mayer's labors has, long after his death, been thankfully and publicly acknowledged by Struve and Mädler. In his two treatises, *Vertheidigung neuer Beobachtungen von Fixsterntrabanten* (1778), and *Dissertatio de novis in Coelo sidereo Phaenomenis* (1779), eighty double stars are described as observed by him, of which sixty-seven are less than 32″ distant from each other. Most of these were first discovered by Christian Mayer himself, by means of the excellent eight-foot telescope of the Mannheim Mural Quadrant; "many even now constitute very difficult objects of observation."

The duplicity of many stars was, of course, known before, but no concern was shown as to whether they were optical or physical pairs; this was first rendered possible by measurements, of which Fr. Christian Mayer made the beginning, and which are even now or only just now being continued with great ardor. Amongst those who paid special attention to this duplicity, we again find some Jesuits, and their observations relate to the southern sky. Humboldt writes:† "* * * I there drew attention to the fact that α of the Southern Cross, * * * is one of those stars whose multiple nature was first recognized in 1681 and 1687 by the Jesuits Fontaney, Noël, and Richaud. * * * This early recognition of binary systems, long before that of ζ Ursæ Maj.‡ * * * is the more remarkable, as Lacaille, seventy years later, did not describe α Crucis as a double star * * * Richaud also discovered the binary character of α Centauri, almost simultaneously with that of α Crucis, and fully nineteen years before the voyage of Feuillée to whom Henderson erroneously attributed the discovery."

The Comets.

The comets also engaged the attention of the Jesuits. Fr. John B. Cysatus is worthy of especial mention in that he was

* The term companion or comes has since that time become standard.—Fr. J. S.

† Humboldt, Cosmos. vol. 3, p. 317, note.

‡ Probably not correct. For Riccioli noticed it already in 1650; perhaps it was noticed before, but I have no evidence.

the first to use a telescope on a comet. It was the comet of 1618. He has published a paper on it, *Mathemata Astronomica* * * * Ingolstadii, 1619, which according to Wolf* "is justly numbered among the most important papers of former times concerning comets." A remarkable passage that occurs in it, has hitherto been overlooked. Wolf says† that Kepler and his contemporary Cysatus in their writings which appeared on occasion of the comet of 1618, already speak of a definite orbit, an almost straight one, of the comet, whilst until then comets were allowed to roam about in a lawless manner. However, Cysatus did not unconditionally trust the straightness of the path. He says that the path from the beginning of December until nearly the 7th of January corresponded to a straight line, but after that less so. "This curvature (of the orbit) would be a phenomenon of great importance, if it could be confirmed by more observations. For I will not come to a decision from the case of this one comet. For it is possible that on account of inadvertance the stars are not accurately plotted on the globe or that the observation of the comet's position in the line of the two fixed stars‡ (although accurately made) is really not so infallible. I therefore leave the case undecided."—The orbit was really not straight but elliptical, and it redounds to the honor of Cysatus that this small deviation from a straight line did not escape him in his observations.

Moreover Fr. Cysatus was the first thoroughly to study the structure of the comet, inasmuch as he was the first to apply the telescope to this purpose. He distinguished the nucleus and the coma in the head of the comet. Both terms remained in scientific usage. He says he had employed much diligence and much time in the work, and had made use of two tubes, one six, and the other nearly ten feet long.

He furnishes a very presentable description, one, in short, like those to be read today in text books of astronomy. Thus, for example, he says expressly that 1. the nucleus was visible, 2. there was a nebulous envelope about the nucleus, and 3. that outside of this envelope there was yet a luminous appearance, but considerably fainter, that therefore there were two brighter rings about the kernel. This may be the first observation referring to it, as it is perceptible only with a telescope, and no one had used the telescope upon comets before him.

* Wolf, Gesch. d. Astr. p. 409.

† Wolf ibidem, p. 410.

‡ He observed the comet's position by alignment.

The extraordinary violent movements of the tail, and its retrograde lengthening and shortening (recounted by Littrow*), are also described in the observation of the 4th of December.

He always measured the diameter of the nucleus as well as of the coma. Once he saw in the coma a small star which he thought belonged to the nucleus; but in an hour and a half it developed into a fixed star by coming out of the coma.

Nebulae.

The same paper also contains the first account of the nebula of Orion, which he brings in as an explanation of the structure of the comet's head. "For the rest Bessel already spoke for the priority of Cysatus, and as his reclamation was little heeded I renewed the same," says Wolf.†—I add also that Cysatus was the first to mention not only the nebula of Orion, but even the so-called trapezium, that is, those stars that are compressed into a very narrow space in the nebula. This is a considerably more delicate discovery than that of the Orion nebula as a whole, and indeed only possible with the aid of a telescope, as Cysatus himself says: "for with the tube one sees, etc." This fact has hitherto remained entirely unknown. He says: "For the rest this appearance is like that of a crowding of stars near the last star in the sword of Orion; for with the tube one sees how in like manner some stars are compressed into a very narrow space, and how round about and between the stars a white light like that of a white cloud is poured out. This crowding of stars, I say, is very much like the head of the comet, only that it has somewhat more the form of a rectangle ("aliquanto oblongior")." It suffices to read this description, to contemplate the drawings of the head of the comet given in Cysatus's work, and to have seen the trapezium, in order to award the discovery of the trapezium at once to Fr. Cysatus.—The discovery of the trapezium is generally ascribed to Huygens, in as much as he declares it to consist of three close stars, to which he added a fourth in 1684; this may be corret, but that Cysatus has nevertheless seen the trapezium without determining the number of the stars, is beyond all doubt. He uses the expression "a few stars" instead of three or four; and as he declares this group of stars to be oblongior, he must have seen at least four stars; and this was as early as the year 1618.

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* Wunder des Himmels, p. 565.

† Handbuch de- Astr. I, 591.

Furthermore, another fact has been overlooked (probably not been read, because it was in Latin; all this being contained in the thirteen lines* in which he refers to the Orion nebula),—that Cysatus mentions also another nebula, which is without doubt the one of which Littrow says: "(AR = 277° 35′, = D — 24° 0′, in Sagittarius), a very fine spherical group, gradually brighter towards the centre, but without a true nucleus. The stars of the 11th to the 15th magnitude appear to be equally distributed throughout, and the boundary of the whole indistinct. Discovered 1655 by Abraham Ile," Cysatus says: "Finally, another nebulous ball, set throughout with small stars, and a little above the arrow of Sagittarius, is also like the head of our comet." As he writes this in 1619, the priority must without doubt be ascribed to him.

The "Nebulosa" appear in general not to have been strangers to Cysatus, as he repeatedly speaks of the stellæ nebulosæ, without adding anything that might show them to be new.

In speaking of comets we must also add the name of Fr. Nicolas Sarrabat, who was the first to discover the comet of 1729, which is marked as a telescopic one. Consequently he was the first to discover a comet with the telescope.

The observation of the zodiacal light, this celestial interrogation point so very mysterious even today, frequently engaged the labors of Fr. Francis Noël (1729, missionary in China) and Fr. Esprit Pezenas, professor of hydrography in Marseilles, later director of the observatory in Avignon, who, according to Wolf,† in 1730 discovered the so-called counterglow (Gegenschein) of the zodiacal light.

Maps of Countries.

It yet remains for me to speak of geodesy and geography, in as far as they pre-suppose astronomical observations. The performances of the old Jesuits in this respect, we may say it boldly, are of extraordinary value. Let us first cast a glance at China, that immeasurably great empire. "In ten years work, says Dr. Wegener,‡ the Jesuits had to sift the rich, extant, and partially newly-made material, and to set it right and complete it by means of a large number of astronomical re-determinations, which they executed in extended journeys throughout the whole

* Mathemata Astronomica, p. 75.

† Handbuch der Astr. II., 504.

‡ Dr. Wegener in the Zeitschrift der Gesellschaft für Erdkunde in Berlin. XXVIII. 202.

empire. The map, thus finished in the year 1718 and copies of it multiplied by means of a copper plate engraving, may unconditionally be put down as one of the greatest performances in the entire history of cartography. One must realize that an enormous area of eastern Asia was mapped upon it in more accurate detail than any one province of the small "Great Powers" of Europe at that time. The accuracy of the positions given upon the Jesuit map, at least in China proper, is so great, that modern deviations must always at first sight be considered with distrust. Thus, for example, the astronomical observations of the Széchényi expedition in the province Kansu proved the Jesuit positions to have been almost throughout more accurate than the deviations of Prshewalki."

Very much had already been done even before the definitive production of the map in 1718. "A decisive progress in the knowledge of China is connected with the appearance of the Jesuit Matteo Ricci, who obtained permission from the emperor in 1600 to make his permanent abode in Peking. Whatever views one may have concerning the political aims of that religious order, the history of the sciences can speak of the Fathers of Jesus only with wonder. Thus we are indebted amongst others to the Jesuit Martini, who returned from Asia to Europe in 1651, for the first atlas of China*, with which the newer knowledge of that empire begins. The Jesuits Grueber and Dorville reached Lhasa from Peking after a dangerous journey of six months, and from there descended to Agra over the Himalayas in 1661."† How many astronomical observations are contained in these few words and under what difficult circumstances!

To give only one example, Fr. Souciet, at the end of the first volume and as an appendix in the second volume, gives 218 positions, mostly from India, China, Thibet, amongst which are 111 from Fr. Gaubil, 89 from Fr. Noël. These are by no means all; but the enormous distances of the individual places sufficiently indicate what a value these determinations represent, as such long journeys through partially inhospitable regions and an unreliable population, journeys with the most primitive methods of conveyance, are by no means to be reckoned among pleasure trips. To these must be added many determinations of position in America, which probably brought many more difficulties along

* Novus Atlas Sinensis a Martino Martini S. J. appeared as the eleventh part of the Novus Atlas absolutissimus of Jansenius, 1655.—Martini was born in Trent.

† Peschel-Ruge, Geschichte der Erdkunde, Munich 1877.

with them and were ascertained mostly only with the gnomon, as it was impossible to drag more instruments along. In this connection a remark inserted by its writer in the article, "Fr. Marquette,* Discoverer of the Mississippi River," is interesting. "For some reason that I am not able to explain, the Jesuit missionaries generally made a mistake of about a degree in their latitude determinations. Every point upon their maps, which are otherwise executed with wonderful accuracy for their circumstances, lies so much more to the south than upon the present maps." There is question of North America in the cited essay. Perhaps this circumstance that the latitudes are all too small by "about a degree," and that this error is constant although the observers are different, may be explained in this way, that many missionaries, who were by no means provided with refined measuring instruments, determined their latitudes by means of the gnomon and took meridian altitudes. They overlooked the fact that the umbral shadow of the gnomon indicates only the altitude of the Sun's upper limb, so that the angle of elevation becomes too great, and the latitude therefore as much too small.—As in China and America, so also in other countries the missionaries did their best to make themselves useful to science. Thus Stöcklein† says of Fr. Neret: "He measured the latitude of every place he visited with the quadrant that he carried with him, and laid off the meridian with his magnetic needle." He occupied himself principally with Syria. And the same author says about Fr. Sicard that the measurements from Pelusium to Suez, Memphis, Cairo, Ramasse * * * and Tur to Sinai, he obtained from Fr. Claudius Sicard, "who not only visited all these places, but also very accurately measured them with the compass and quadrant, and moreover, in regard to measuring the length of terrestial arcs, drew the first meridian arc * * * through the city of Paris."

We might yet mention the maps of the various countries which the Jesuits penetrated as missionaries. Thus the Benedictine Knogler‡ writes to v. Zach: "I have * * * all respect * * * for the Macartney map; but in regard to the Chinese Wall I cannot consider it correct. This I have much more accurately and in greater detail on a map of Tartary (more correctly Mongolia)

* "Alte und neue Welt," 1876, p. 646. Note 2.

† Allerhand So Lehr—als Geistreiche Brief, Schriften u. Reis—Beschreibungen, welche von denen Missionariis der Gesellschaft Jesu * * * in Europa angelangt sind. Augspurg und Grätz, 1728.

‡ Monatl. Korrespondenz, 1800, March, p. 247.

executed by the Jesuits, which however is not engraved. On this the Wall looks very different. I can also send you a map of California drawn by the Jesuits." And v. Zach remarks hereupon: "Although the coasts of California have become more accurately known * * * since the observations of the latest circumnavigators, these older maps of the Jesuits may yet furnish a knowledge of the interior of the country which we do not up to the present possess, and therefore give a valuable contribution to the knowledge of countries." And Humboldt writes:* "Fr. Fritz had come to Quito with another German Jesuit, Fr: Richter; he drew up a map of the Amazon river in the year 1690, the best that could be had before La Condamine's journey." La Condamine himself, who travelled the same way, declares the map of the missionary Fritz to be "a valuable and unique piece, and one proving the ingenuity of its author." He there points out the enormous difficulties of the journey and the lack of instruments.

Equally remarkable and sensational was the map made by Fr. Francis Kino, born in Trent, apostle of Sonora in California, on which he drew the land route he had discovered to California in 1701, and thereby proved beyond doubt that California was a peninsula.

Fr. Adam Gilp (from Bohemia) designed a map of the province of Serres in the country of Sonora.

Fr. Liesganig superintended the construction of a large map of Galicia, consisting of 94 sheets, of which v. Zach says:† "The survey of Galicia was made under the direction of Liesganig (not without opposition on the part of some noble ignoramuses and surveyors) according to the well known and only true astronomical-trigonometrical method." At his side were the two Jesuits, George, baron of Mezburg and Francis Guessman. Mezburg later on conducted the survey of the west of Poland, that had been newly acquired, and began the map that Triesnecker completed. He also issued a postal map of the Austrian hereditary possessions. Fr. Christian Mayer did similar work. He published a "Charta geographica per tractum Rhenanum Moguntia Basileam usque."

The map of Carinthia by Fr. Charles Andrian, S. J., is also mentioned as a "beautiful and correct" one.‡

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* Humboldt's Travels to the Equinoctial Regions of America. Hauff's German Translation, vol. 5, p. 255. Stuttgart 1862.

† Monatl. Korresp. 1801 p. 554.

‡ Mitteil. des k. k. militärgeogr. Instituts. V. 1885 p. 152.

Fr. Claudius Dechalles is also worthy of remark. As professor of hydrography in Marseilles "he there drew up a large map of the Mediterranean Sea resting upon astronomical observations, which was never indeed engraved but far surpassed the contemporary very erroneous maps."

In cartography mention must also be made of Fr. Nicasius Grammatici (1684-1736), of whom v. Zach reports:* "Nic. Grammatici of the Society of Jesus is known to all astronomers by his writings. * * * He deserves to be placed among the number of those astronomers whom we * * * have specially cited as being the first in the construction of geographical maps to have regard to the oblateness of the Earth and to recommend it to others."

While he may not independently have designed maps of countries, Fr. Ignatius Weinhart, professor of mathematics in Innsbruck, yet has rendered great service in this direction, as the famous "Bauernkarte" [Peasants' map] is, so to speak, due almost entirely to him.† For he had taught the Peasant Peter Anich surveying and the manufacture of suitable instruments, as well as making the necessary astronomical observations. Later on, after Anich had developed into a thorough geometer, Fr. Weinhart was authorized by the government to superintend Anich's survey of the Tyrol. In 1766 came the order "to take the Original-Mappam, as it had been designed by the late Peter Anich * * * and to copy it most accurately under the supervision of Professor Fr. Weinhart." For superintending and supervising the whole enterprise, Fr. Weinhart repeatedly received the highest acknowledgments and a medal of honor bearing the effigies of the empress and her consort.

Measurements of Terrestrial Arcs.

It yet remains to say a word about the measurements of terrestrial arcs. While the efforts of learned men at the end of the 17th century were being directed towards determining the size, and later on also the shape, of the Earth, the Jesuits also from that time on took a modest part in this by no means easy affair. Fr. Riccioli and Fr. Grimaldi in 1645 were the first to attempt the measurement of a degree of the meridian by means of mutual terrestrial zenith distances. It probably came out too large. For "this measurement of terrestrial zenith distances would be

* Monatliche Korrespondenz, Vol. I, p. 241. Note.

† Mitteilungen des k. k. militargeographischen Institutes. V. 1885, p. 106 seq.

the simplest and best means of measuring the Earth if refraction did not exist or at least if it were more amenable to computation than has hitherto been the case."*

Upon this followed in the year 1702 the measurement of the arc which Fr. Anthony Thoma undertook in China and near Peking.† For it was in December 1702 that the emperor Kang-Hi ordered Fr. Thoma to measure a degree upon a large plain near Peking in company and with the co-operation of his third-born Prince, and in the presence of many mandarins of the Mathematical Tribunal. The presence of the imperial prince, who was himself a lover and connaisseur of mathematics, in which the Jesuits had educated him, and of the mandarins who were so very inimical to the European mathematicians, admits of our conjecturing with good reason that Fr. Thoma would not be wanting in diligence and in the exactitude of his measurements. The result is given in Chinese and also in old-Roman scale.

It is only the difficulty of reducing the unknown Chinese foot. and in like manner the old Roman foot, to the French scale that is in the way of our arriving at an exact knowledge of the result. Knogler,‡ who occupied himself with the case, took the mean of the lengths of the old Roman foot given by various writers in comparison with the French, and thus obtained a result that was only nearly 24 toises in excess of the one computed (in 1800) with the latest value of the ellipticity. However this is always very uncertain. There is a remarkable passage in Baron Richthofen in regard to this. He says that the Jesuits in China always endeavored to introduce a scale of measurement that was definite and easily comparable to the French, and that for the reason of being able to make their measurements more accurate, they concluded to put 200 Li equal to an equatorial degree. Kang-Hi established this as the official standard, and even at present it serves as the norm most frequently used for computation. The length of such a Li is 556.5 metres. Now 200 such Li are equal to 111,300m. But according to Jordan an equatorial degree is equal to 111,306.6m. No second arc measurement was undertaken in China, and as the establishment of this standard comes from the emperor Kang-Hi, there can be no doubt that the 200 Li = 111,300m. mentioned by Richthofen are deduced from this base measurement and seem to come very near to the truth.

* Handbuch der Vermessungskunde of Dr. W. Jordan. Stuttgart 1878. Vol. 2, p. 4.

† Monatl. Korrespondenz of v. Zach. 1800. March and June.

‡ Monatl. Korresp. Ibidem.

For only two assumptions are possible: either at the computation of this equatorial degree the view of the French Academy at that time, which considered the Earth as a perfect sphere, was adopted, and then the value of the degree is about 140 toises too great, or Newton's oblateness (1/229) was used, and the truth was approached more closely. That the second assumption is the more probable appears from the expression "*equatorial* degree." which has no real meaning in the first assumption.

Upon this followed in 1775 the arc measurement of Fr. Boscovich and Fr. Maire and yielded a result which, according to Wolf,* "does all honor to the two geodetes, if we consider the instrumental means at their disposal." The occasion† of this measurement was "the want of agreement of the arc measurements of Peru, France and Lapland, which had led Boscovich to the idea that the Earth was perhaps not an ellipsoid of revolution * * * and that in order to answer this question it would be useful to measure another degree in the same latitude with the French one but in a different longitude. With the means then at hand, however, the measurements thereupon undertaken by him could impossibly lead to a decisive result * * *; on the other hand the train of thought of Boscovich, and especially the method, according to which he somewhat later on deduced the most probable value of the ellipticity (1/273) from the results of all the measurements accessible to him, represented for geodesy the dawn of a new day."

In regard to this arc measurement Wolf says:‡ "The sole important advance at that time was that at his arc measurement in the States of the Church Boscovich departed from the customary application of contact measurements * * * he then did not in practice bring the rods to a complete contact, but determined by means of a dividers and plotting scale the distance of the contiguous points."

It appears from the publications of the royal imperial military geographical institute¶ that Fr. Liesganig began the astronomical geodetic survey in Austria-Hungary in 1762. He undertook the measurement of a meridian arc at the command of the empress Maria Theresa. The apparatus constructed by Liesganig for the measurement of the base of the newer part of Vienna

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* Wolf, Handbuch d. Astr. II, p. 193.

† Ibidem.

‡ Handbuch d. Astr. II. p. 15.

¶ 1884 p. 176 seq.

served for such measurements until 1810. Gunther* remarks upon this: "Liesganig's work does not enjoy a particularly good reputation on account of its result, but it is not to be denied that its plan completely corresponds with the scientifico-technical norms that were considered the standards at that time; especially the considerations concerning the differences in the length of a Steyermarkian and of a Croatian degree, which are said to be conditioned by the attraction of the mountains, give no unfavorable testimony to the criticism of the learned Jesuit. His computations therefore must have been injuriously influenced by some constant errors of a particular kind."

Finally Fr. Christian Mayer measured a degree in the Palatinate, as he says in a certain publication.†

Published Works.

In conclusion yet a word about the literary activity of the Jesuits. Amongst the many works I call attention only to those that were considered important at their time and enjoyed praise or acknowledgment among the learned. I omit the various publications of the observations.

Amongst the astronomical writers the oldest of them must be named first. This is Clavius. Christopher Clavius, called the Euclid of his century, was born in Bamberg in 1538. At the age of 17 he entered the Society of Jesus, in which he distinguished himself in mathematics. Pope Gregory XIII made use of his knowledge for the reform of the calendar, which he had repeatedly to defend against many attacks. He died in Rome in 1612. Amongst his 26 works, of partly mathematical, partly astronomical contents, many of which passed through various editions and that in folio. I call attention to the following and add the judgment of Houzeau:‡

Commentarius in sphaeram Joannis a S. Bosco.—"This treatise is the best commentary ever written on the astronomy of Sacrobosco."

Gnomonica libri 8 * * * 1581.—"This is the greatest work on gnomonics that exists, a work that may be considered an encyclopedia of skiatherics."

Rom. Calendarii a Gregorio XIII. restituti explicatio 1603.

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* Günther, Lehrbuch der Geophysik u. phys. Astronomie. Stuttgart 1884, Vol. 1, p. 144. Note.

† Basis Palatina * * * exeunte aune 1762 ad normam Academiae regiae Parisinae scientiarum exactam bis dimensa * * * a Chr. Mayer, S. J.

‡ Houzeau Vademecum de l' Astronomie, p. 110.

"Gives the completest idea of the elements of the Gregorian reform."

Next there are some noteworthy works on Chinese astronomy. To these belong Fr. Gaubil's Traité de l'Astronomie chinoise, "an important work."* Then Liber organicus by Fr. Verbiest, but especially his "Astronomia europea sub imperatore * * * Cam Hi * * * in lucem revocata * * * Dilingæ 1687." "This book is necessary for those who wish to learn the astronomy of the Chinese."† These are the most important among the many works on astronomy in China. We might also mention the various star tables, edited with Chinese text by the Jesuits, especially the planispheres, which were published after a work of Fr. Pardies and contain star positions projected upon the faces of a cube circumscribing a sphere. Fr. Pardies had invented this method of projection.

J. B. Riccioli (Ferrara 1598, Bologna 1671) published various works on astronomy, but the most important is his Almagestum novum * * * Bononiæ 1653. Fol. and Astronomia reformata * * * Bononiæ 1655. Let us first listen to the weighty judgment of v. Littrow on Riccioli: "The well known Jesuit Riccioli has occupied himself very much with the Moon and with the whole of astronomy generally, without however thereby advancing this science very much."‡ Very flattering! J. C. Houzeau in his Vademecum de l' Astronomie (p. 116) entertains a somewhat different view when he writes: "Riccioli Almagestum novum. This immense work, a treasure of astronomical learning, forms a veritable encyclopedia of the science of the stars." And "Astronomiæ reformatæ tomi 2. The collection of observations, which forms the tenth and last book, is a valuable source." An old savant had called the Almagestum novum the pandects of astronomical knowledge.¶ It seems therefore that v. Littrow has accidentally overlooked these two works or not known of their existence.‖ The object of this colossal work is given by Riccioli

* Houzeau, p. 44.

† Houzeau p. 44.

‡ Die Wunder des Himmels, 7th edition, p. 401.

¶ Morhof Polyhistor, t. II, vol. II, p. 347.

‖ [Compare Newcomb's vindication of Hell against the misrepresentations of Littrow in the Astronomical Papers of the American Ephemeris, vol. II, pp. 301, 302: "The conclusion was reached that Littrow's inferences were entirely at fault * * * Littrow's mistakes were due to the fact that he was *color-blind to red*, in consequence of which he wholly misjudged the case on first examining the manuscript, and afterward saw everything from the point of view of a prosecuting attorney."—Transl.]

himself in the preface with sufficient explanation. He intends to offer "an astronomical work, which may be a kind of library for the men of our Society and for others who cannot have access to the great number of such books or the leisure to read them, a work, in which I have collected with the greatest clearness the whole of the old and the new astronomy, together with the controversies that occur therein." The work becomes yet more valuable on account of a personal index, used perhaps for the first time, in which nearly all the persons mentioned in the book are recounted and accompanied by the data of their lives. The work also contains a number of accurately stated observations made by himself as well as by others.

Maximilian Hell, a Hungarian, born 1720, died 1792. When Maria Theresa in the year 1756 erected the observatory at the Vienna university, Hell was called to be its director on account of his attainments, and remained in this position during 35 years until the end of his life. A call to England with a considerable salary, which he received at the time of the Suppression of the Society, he declined. Amongst the many works that he published the ephemerides deserve particular mention. This was the first undertaking of its kind after the Connaissance des temps, the first therefore in German countries.

The ephemerides appeared each year and always contained appendices, that is, treatises on various astronomical subjects. The first were published from 1757 until 1792; from that time on Fr. Francis Triesnecker undertook their continuance until the year 1806. Triesnecker himself wrote astronomical works and treatises; but perhaps it redounds more to his praise that he "was an unselfish astronomical computer,"* who at once used the many observations of occultations reported to him for the determination of positions (in longitude).

Roger Boscovich (Ragusa 1711, Milan 1787) might also be mentioned. Amongst the nearly 70 publications of this genial man, of partly mathematical, partly astronomical contents, there are many very excellent ones, as for example, the one on gravitation; again, about comets "de orbitis cometarum determinandis 1774;" and "De annuis fixarum aberrationibus," in which he gives formulæ for the change of position caused by parallax and refraction. All these works Houzeau mentions in an especial manner.

May these few works among the many suffice to show that the

* Wolf, Handbuch d Astr. II, p. 311.

old Jesuits have produced something worthy of mention in astronomical literature.

With this I deem my task accomplished, in that I have briefly shown the intimate relationship of the old Jesuits to astronomy, principally by recounting their observatories, by giving their performances in respect to astronomical instruments, their more remarkable observations, some priorities especially, their application of astronomy to cartography and arc measurements, and finally by mentioning some of their numerous astronomical writings. I believe the activity of the Society of Jesus in this field will not be undervalued, but it will be acknowledged that she has done much for her circumstances. To present this truth in its proper light, was also the purpose of these lines.

THE SUN'S MOTION REFERRED TO A GROUP OF FAINT STARS.

GEORGE C. COMSTOCK.*

A year ago I presented to this Society a set of proper motions of faint stars (ninth to twelfth magnitude, distributed throughout the twenty-four hours of right ascension) determined from micrometric observations extending over a period of about half a century. During the past year I have derived from these proper motions a determination of the direction and magnitude of the Sun's motion using Airy's method for the formation of the necessary equations. This method requires that some assumption shall be made with regard to the distance of each star employed and for this purpose I have used an extrapolation of Kapteyn's formula which represents this distance as a function of the proper motion and stellar magnitude.

I have thus derived from absolutely new data, no one of the proper motions employed having entered into any previous investigation, the following co-ordinates of the apex of the solar motion:

$$\text{R. A.} = 297^\circ \qquad \text{Decl.} = +28^\circ$$

The mean result of previous determinations from brighter stars is R. A. = 275°, Decl. = + 30°. My solution furnishes as the linear velocity of the Sun's motion 4.8 radii of the Earth's orbit per annum, which compared with Campbell's spectroscopic result, 4.2 radii per annum, indicates that the assumed parallaxes

* Read at the meeting of the Astronomical and Astro-Physical Society of America, St. Louis, Dec. 30, 1903.

of the stars are not greatly in error. Adjusting the assumed distances so that the resulting solar velocity shall agree with the spectroscopic determination I find for the average parallax of 67 stars included between the ninth and twelfth magnitudes, $\pi = 0''.0051$.

This number, 67 stars, represents the entire amount of data at my disposal, no proper motion having been rejected in the discussion, but it is, doubtless, too small a basis for a determination of the elements of the solar motion and at least provisionally, I prefer to interpret the results noted above as evidence that the proper motions obtained for these faint stars are real quantities and that the methods employed for their derivation may with advantage receive wider application. I have now in hand a similar determination of proper motions of all stars fainter than the eighth magnitude for which suitable data can be obtained from the earlier double star observations of the Struves.

WASHBURN OBSERVATORY, Dec. 24, 1903.

SEEN AND LEARNED ABROAD.

T. D. SIMONTON.

FOR POPULAR ASTRONOMY.

A trip abroad is a rest, a diversion to a business man—it may also be an education; and especially may it be this to the man of science, or to the lover of science, with the latter of whom I claim my place. To both these seekers after increased knowledge must the variety and the expansion incident to a European journey and residence be a God-send of opportunity. The writer has never ceased to appreciate his experience of a year and a half so spent, but now so many years ago, 1887-1888, that he should never have thought of recounting incidents thereof for publication, save at the earnest solicitation of the editor of this journal, who was complimentary enough to say that not alone what was strictly new, but even what many of us may have read about, might come with interest from the hand of one with whom it was a matter of personal experience. In response he shall endeavor to select such matter—largely from a personal journal kept at the time—as may not be inappropriate to a place in these pages.

When out for days beyond the sight of land we realize the fitness of the expression "the great deep," and that regarded from the outside—as possible observers upon Mars may scan our

planet—we must appear in a general way a remarkably smooth and uniform spheroid (most likely *sphere*, unless their instruments surpass ours), details of which are provokingly hard to make out, since we are always immersed in the sunbeams when nearest to them. However, our permanent ice caps at either pole may be a consolation to them and a starting point in seeing likeness in us to themselves. We are led to a new and more vital appreciation of what our astronomers and mathematicians have done for us, when we see the ship's officer day by day, by a simple observation or two of the Sun, turn into his room with the utmost confidence that he has secured the position of the ship upon the great ball of water presenting the side of a world.

In a word permit me to say our journey, that of my wife and myself, included England, Scotland, Wales, Ireland, and the continent as far as Rome, with a residence of weeks, and even months, in such centers as London, Edinburgh, Berlin and Rome.

As we decided upon our lodgings in Edinburgh I noticed a door plate on the front of the next house, "Challenger Expedition." Simply by accident we were planted for weeks next door to the headquarters of that great expedition of research upon the sea that after three years' absence had returned with its treasures of fact and material from the great deep, and where the collating and editing of the matter of the expedition was going on. Of the 32 great volumes finally issued, 23 were completed. Sir Wyville Thompson had been editor-in-chief, but his death had caused the work to fall into the hands of (now Sir) John Murray. This I had already learned, as also many other facts that prepared me for matters of science abroad from my reading of "Nature" for years. Within a day or two I was favored with an introduction to Mr. Murray. He turned from his desk, and finding in me an American who knew something of the great Expedition, his interest and kindness could not have been surpassed. He explained how the work of editing was planned and effected—how the treasures of research in the museum in another room, which I was permitted to inspect, even handle in some instances, were placed in expert hands in the kingdom, on the continent, and in America, so that whether it were matter for the chemist, the geologist, the naturalist, the biologist or the ichthyologist the best results might be obtained from their assiduous studies and reports. It was indeed a privilege to look over the treasures of their research and their dredgings in all seas, in some instances of fish or shell or strange creature the sole example in the possession of man was there to be seen. I asked about a heavy piece of

stone lying on the floor. "Oh, that is a piece of the Antarctic Continent." Before leaving the room Mr. Murray had said to me, "These two volumes, The Narrative of our Expedition, are at your service while you remain in Edinburgh; take them to your lodgings next door;" On a subsequent visit I had considerable conversation with him on his favorite themes of oceanic research and Antarctic exploration. Before leaving he gave me 3 specimens in vials of deep* dredgings specially arranged for microscopic examination. "Globigerina ooze, depth 1450 fathoms, Diatom ooze, 1950 fathoms;" and lastly (to show detail of record on all the vials) in full, "Radiolarian ooze with Globigerina, No. 271, Date Sept. 6th, 1875, Lat. 0° 33′ 0″, Long. 151° 34′ W., Depth 2425 fathoms"—nearly three miles.

July 25, 1887. "Went to see Mr. Buchan the meteorologist at his office, 122 George St. He is completing the meteorological work—the reductions, tabulation and results—for the Challenger Publications. He showed me his sheets in progress. Introduced me to his assistant and said they both expect to be at the Meeting of the British Association at Manchester. He encouraged me to try to be present—which I now begin to think I may. Mr. Buchan is an enthusiastic meteorologist, and has charge of the Ben Novis Meteorological Observatory, noted for its elevated position and also for its equipment. He showed me the first specimen of stellar photography I have seen, the work of Mr. Roberts living near Liverpool. I was delighted with the plate, and can conceive that here is a great aid to certain kinds of astronomical research."

July 18. "Had an invitation from Mr. Murray to the Meeting of the Royal Society of Scotland, to which I went at 8 P. M. Some ten members sat around a table. A gracious, large mouthed, fine looking gentleman, Sheriff Irvine, of Drum, was in the chair. A score or two persons were there on invitation also, like myself.

Several papers were presented and on subjects abstruse enough; yet the business was so managed that it was in no sense tedious. Not one of the papers was read in full. The introduction perhaps was given, and then a summary of the points presented. The rest was left to be looked up when the paper should appear in print. Several of the papers (from different authors) were presented by the same large, slightly bald, broad faced gentleman, and it seemed to me, with admirable clearness and comprehensiveness. I had been introduced to a member, Lord McLaren,

* If any of the readers are enthusiastic in microscopic research I could spare samples of all these vials for their gratification. The supply was generous.

one of the judges presiding over the courts in Edinburgh, and asking him who it was that was able to present so admirably those varied papers, he replied, 'That is Professor Tait.' Mr. Buchan, the meteorologist and Mr. Murray each presented a paper also in good style. The whole meeting was over and we had our cup of tea in the rear room before 10 P. M.

At the Museum of Arts, Sciences and Antiquities, amid a world of interesting objects, I was especially attracted by an immense stalagmite from a cave in Java. It is in size, shape and appearance so much like a large saw-log that I had to read the description of it to be sure it was not a petrified tree trunk. It must be more than 30 inches in diameter and about 20 feet long. Was brought over a hundred years ago from Java, through the scientific curiosity and liberality of a naval officer. A short stump was left where it was sawed off. The cave was again visited by the recent Challenger Expedition and the stump examined and noted to be covered with some nodules of matter deposited from the dripping water. The cubic contents of these nodules were carefully measured, and taking into account their volume, the time taken for their formation, and a like rate of deposition accorded to the original stalagmite, when sawed off it must have been 600,000 years old!

In the Botanical Gardens and Arboretum of Edinburgh we found a place of some 70 acres, a treat to the eye and the lungs. The "Rock Gardens" consisted of mounds and walks set off with any kind of rough stones for ferns and all kinds of hardy plants. Alpine plants and various species of sempervivum were numerous."

If it were not too discursive I might tell how with the co-operation of botanist, the landscape gardener, the architect and artist, what was once a great rough ravine in the very heart of Edinburgh, has been transformed into the charming Princes Street Gardens, one of the leading attractions of the city, with its bright public buildings and statues to honored citizens gleaming amid a profusion of grass, plants and flowers. For the engineer I might refer to the great North British R. R. bridge under which we passed, then being thrown across the Firth of Forth with its main spans of 1700 ft. and its workmen on its high towers (360 ft. aloft) dwindled to pigmies. I might tell of the Caledonial canal cleaving Scotland diagonally from southwest to northeast by utilizing the waters of certain lochs, so that we could reach Inverness on Moray Firth of the North Sea, passing through the midst of the highlands and having Ben Novis

(4406 ft.) a prominent land-mark half the way. If I had space to describe possibly I might interest the geologist in a personal visit to Fingals Cave, which at a little distance seems to be a door-way into a steep island resting on myriads of hexagonal iron (really basalt) columns, some of which having been undermined by the sea, have fallen, making the opening of the cave, into which we were permitted to go by boat from our steamer. Or I might refer to the Giants Causeway in Ireland as consisting of similar columns projecting up from the shore and out of the water of the sea, and broken off at varying heights. The student of forestry would be interested in the approach to the seat of the Duke of Argyle, through the finest display of planted forest trees we have ever seen. The pines were simply magnificent. A record says, "this forest was planted by the great Marquis of Argyle, leader of the Covenanters, and finally executed in Edinburgh in 1661." It requires some effort to believe this, so natural does the wild and bestrewn forest look now.

At Port Rush, after a splendid coach ride clear round the northeast end of Ireland, we hoped to have a ride upon the first electric road ever built—to be driven by the water power of the Falls turned into electricity. It was a measurable success for a time, with its "third rail" at one side a foot or two above ground. Though at that time disused to our great disappointment, as a first move toward what has since been accomplished in electric traction it was an honor to him by whom it was invented and installed—Sir William Siemens—to whom also we are under great obligation for the construction of the first Atlantic cable. A memorial window in Westminster Abbey is a fitting recognition of the services of this eminent man of science.

STATISTICAL COMPARISON OF THE MINOR PLANETS AND THE SHORT PERIOD COMETS.

M. O. CALLANDREAU.*

The great number of small planets give us today very favorable conditions for statistical research, as Monsieur de Freycinet and Monsieur Jean Mascart pointed out a short time ago.

It is well known that in the average of numerous results the individual anomalies disappear and general laws are made manifest.

* Translated by Miss Isabella Watson.

To avoid too frequent corrections we may limit ourselves today to the consideration of the whole number of planets discovered in the 19th century, a number scarcely less than 500.*

In the following table the distribution of the elements is indicated: eccentricity, inclination, semi-major axis and perihelion distance when the aphelion distance, equal to $a\ (1 + e)$ in ordinary notation, is taken as an argument, as it is natural to do for a comparison with cometary orbits. The second column: *Number*, indicates the numbers of the aphelion distances included within the respective limits.

Limits of Aphelion Distance.	Number.	Means of Eccentricities.	Means of Inclinations. °	Means of Semi-major Axes.	Means of Perihelion Distances.
....	....	....	....	....	....
2,35-2,44	5	0,075	3,7	2,24	2,07
2,45-2,54	19	0,099	5,7	2,29	2,06
2,55-2,64	16	0,100	5,4	2,35	2,12
2,65-2,74	23	0,122	5,9	2,41	2,12
2,75-2,84	34	0,141	8,0	2,46	2,13
2,85-2,94	43	0,122	7,3	2,60	2,29
2,95-3,04	40	0,131	7,2	2,65	2,32
3,05-3,14	41	0,127	7,9	2,75	2,41
3,15-3,24	43	0,144	9,9	2,80	2,40
3,25-3,34	45	0,155	9,5	2,86	2,43
3,35-8,44	40	0,161	10,7	2,94	2,48
3,45-3,54	36	0,174	8,5	2,99	2,48
3,55-3,64	24	0,188	10,7	3,03	2,46
3,65-3,74	19	0,194	8,5	3,09	2,49
3,75-3,84	18	0,201	11,7	3,17	2,54
3,85-3,94	7	0,212	6,3	3,21	2,54
....	....	....	....	....	....

We have not considered the results for which the averages depend on less than five numbers.

According to the table the aphelion distances scatter themselves symmetrically around their mean just as the accidental errors do. The mean, as M. Jean Mascart has noticed, is found near to the distance corresponding to the great gap, for which the average movement of the small planets is about double that of Jupiter.

The eccentricities increase quite regularly; yet there seems to be a slight discontinuance for the average aphelion distance, the numbers increasing noticeably when you pass from the upper to the lower part of the table.

The inclinations give occasion for similar remarks, except that

* The tables for the history and statistics of the minor planets, published in 1901 by Dr. J. Bauschinger include, it is true, the history of the planets discovered in the 19th century. But I have used the Annuaire du Bureau des Longitudes in my statistic abstracts begun some years ago; the last planet is numbered 470.

a progressive increase is not shown in the second series of numbers.

For the perihelion distances we notice that the numbers at the beginning and those of the second half taken separately, are almost identical; also that the difference of the two groups is small in comparison with the increase of the aphelion distance.

In the following table is shown, taking as an argument the longitude of the aphelion, the distribution of the elements: *e*, *i*, *a*, *a* (1 + *e*); the second column: *Number* shows the number of elements included between the respective limits.

Limits of Longitude of Aphelion.	Number.	Means of Eccentricities.	Means of Inclinations.	Means of Semi-major Axes.	Means of Aphelion Distances.
° °			°		
0– 20	16	0,100	8,2	2,80	3,14
20– 40	12	0,142	7,8	2,72	3,12
40– 60	19	0,124	10,5	2,77	3,12
60– 80	19	0,144	9,0	2,79	3,19
80–100	25	0,120	8,4	2,69	3,01
100–120	16	0,161	10,6	2.76	3,21
120–140	28	0,175	8,8	2,78	3,26
140–160	43	0,150	7,2	2,71	3,11
160–180	37	0,180	3,5	2,77	3,26
180–200	47	0,148	9,2	2,76	3,16
200–220	34	0,162	9,4	2,80	3,26
220–240	42	0,150	8,2	2,78	3,20
240–260	31	0,152	7,4	2,81	3,23
260–280	28	0,137	9,0	2,86	3,26
280–300	17	0,145	8,5	2,87	3,27
300–320	25	0,129	7,6	2,71	3,06
320–340	13	0,154	10,2	2,75	3,18
340–360	15	0,110	8,8	2,80	3,11

It seems according to the numbers, and the thing is still more evident in a graphical representation, that the distribution is nearly symmetrical with relation to the longitude intermediate between 180° and 200°, that is, near to that of the aphelion of Jupiter: the aphelia of the small planets tend to go in the direction of that of Jupiter; there are 306 on the one side, 161 on the other.*

But we notice besides the constancy of *i* and especially of *a* for the different values of the longitude.

My object has been to establish a comparison of the asteroids and the short period comets, whose number at present is 31; these, being situated at the outer limit, as it were, of the ring of asteroids, seem to differ from them only by their physical aspect.

* This fact has been noted for a long time. Newcomb explained it in 1862, in No. 1382 of the *Astronomische Nachrichten*, by the secular perturbations of Jupiter. M. Doberck published in 1879 tables extending to 191 planets. The theory agrees with observation.

The recent discoveries have made known cometary orbits but little different from the circle, with large perihelion distances. The Holmes comet might have been considered an asteroid during the stellar period. On the other hand there are asteroids, like (345) Tercidina, not to mention Eros, subject to variations in brilliancy; others that could never be found again, perhaps because their existence was ephemeral like that of the comets. Kirkwood discussed in 1888 the question of the origin of short period comets. The difficulties of the capture theory, which explains by the disturbances of the large planets the changing of the parabolic orbits of comets into contracted elliptical orbits, seemed to him so great as to make him prefer the theory which sees in these comets asteroids which have undergone more than others the disturbances of Jupiter; the variations in brilliancy could come from a physical action accompanying the disturbances and more marked when the bodies approach each other. Although the number of comets of short period is still moderate, a statistical comparison is not without interest for solving the problem.

The elements of the tables given below were taken from a list published by M. Fayet (*Bulletin astronomique*, 1899), completed with the *Connaissance des Temps* for 1905.

Limits of Aphelion Distances.	Number.	Means of: Eccentricities.	Inclinations. °	Semi-major Axes.	Perihelion Distances.
4,00–4,49	....	....	....	....	....
4,50–4,99	6	0,56	16	3,13	1,40
5,00–5,49	7	0,59	8	3,31	1,38
5,50–5,99	10	0,66	18	3,45	1,20
6,00–6,49	5	0,71	11	3,64	1,05
6,50–6,99	....	....	....	....	....

Limits of Longitudes of Aphelion.	Number.	Means of: Semi-major Axes.	Inclinations. °	Aphelion Distances.	Perihelion Distances.
....	..	....	....	....	....
40–100	4	3,21	12	5,22	1,19
100–160	5	3,37	10	5,40	1,34
160–220	9	3,57	14	5,83	1,32
220–280	8	3,41	14	5,54	1,29
280–340	4	3,17	15	5,60	0,72
....	..	....	....	....	....

The results not considered depend on only one number. We find for the short period comets the analogue of the distribution for the small planets; the aphelion distances are scattered about a distance little different from the aphelion distance of Jupiter, the eccentricity seems to increase with the aphelion distance while

the inclination shows no tendency to increase. It is clear that bodies having a considerable aphelion distance escape observation the less easily because the eccentricity of the orbit is greater. Note the decrease of the perihelion distances contrary to what was found in case of the asteroids.

The second table, where the longitude of the aphelion is taken as the argument, shows clearly the symmetry with relation to the aphelion of Jupiter and the exaggeration of the numbers of aphelia in agreement with that of the planet (22 to 9, taking into account a number not inscribed in the table). The inclination is almost constant, but the semi-major axis and the aphelion distance remarkably constant, especially the first, for the small planets, seem to depend here on the aphelion of Jupiter. The corresponding perihelion distance is greater while we find it a little less for the asteroids.

The comparison of the aphelia with the nodes of the asteroid orbits shows a characteristic difference. Taking the whole number of asteroids for which the inclination is more than the average 8° we distinguish no grouping. For the 25 orbits of inclination greater than 20°, 18 to 7 aphelia are in the hemicycle which surrounds the node. But there is nothing striking as in the case of the short period comets, where the rule is that the aphelion is near to the point of closest approach to the orbit of Jupiter; just where the action ought especially to be produced and at a relatively recent date for each comet, since, contrary to the asteroids, there is but a slight dispersion of the aphelia to the one side or the other of the plane of the orbit of Jupiter.*

Now let us come to the effect of the disturbances of Jupiter on the form of the orbit.

Taking the simple case of an orbit within that of Jupiter, in the same plane, and utilizing certain remarks of M. Schulhof (*Bull. astr.*, 1898, p. 338), it is at once easy to show that the perihelion distance q of an orbit comparable with that of an asteroid, diminishes when the eccentricity e increases.

In fact, we deduce from the known relation between a and e,

$$\frac{1}{2a} + \frac{\sqrt{a(1-e^2)}}{a'^{\frac{3}{2}}} = \text{const.}$$

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* It would have been better to refer all the orbits to the plane of the orbit of Jupiter, as M. Jean Mascart did for the 417 first small planets (*Bulletin astronomique*, 1899); the conclusions would probably not have been appreciably different.

(a' radius of the orbit of Jupiter), the differential relation

$$\left((1+e)\,q^2-(1-e)\,a'^{\frac{3}{2}}\sqrt{q\,(1+e)}\right)dq$$
$$+\left(q^2-a'^{\frac{3}{2}}\sqrt{q\,(1+e)}\right)qde=0;$$

the coefficient of dq is < 0, as also that of qde, if

$$\left(\frac{q}{a}\right)^3<\frac{(1-e)^2}{1+e}.$$

For different values of e the superior limits of q are given below:

Values of e............	0,40	0,50	0,60	0,70
Limits of q...........	3,3	2,9	2,4	2,0

M. Schulhof mentions as an example the comet 1867 II, whose orbit is subject to great variations of eccentricity in a rather short period of time. At the same time that q is decreasing, which tends to bring the object within the sight of the observer, the orbit is lengthening, and the comet, in case of a meeting with Jupiter, remains for a long time in the neighborhood of the planet and undergoes great disturbances.

But there is reason for considering other things besides the mechanical action.

It is natural to admit that Jupiter, which shows so much affinity with the Sun, exercises on the materials of the planets passing in his vicinity a physical action similar to that of the Sun; that the comets then experience some changes in their internal structure, accompanied by an increase of their brilliancy more or less permanent. This explains the fact proved by M. Schulhof that many periodical comets have been discovered soon after their passage in the vicinity of Jupiter. It should be noted that, if the intrinsic influence of the planet is small, it exercises itself during a much longer time than that of the Sun; it acts especially at the aphelion, and that explains in turn that the corresponding perihelion distances are the greater, as one of the above tables shows.

To sum up:

At the inferior limit of the ring of the asteroids, for the small aphelion distances, we have small eccentricities and inclinations. The eccentricities increase with the aphelion distance, without its being the same with the inclinations. The perihelion distances scarcely increase at all. The orbits seem to be capable of division into at least two groups. The action of Jupiter becomes manifest in the distribution of the orbits.

Farther away, at the outer limit of the zone, the short period comets show a special distribution. The great variation of the eccentricity in short intervals, followed by a diminution of the perihelion distance and an appulse toward the orbit of Jupiter, the double action of the planet, mechanical and physical, explain the apparition of new comets; feebly constituted, they are not long in dissolving, thus leaving a provision of matter available for other formations.

The ideas given above about the origin of cometary materials do not essentially differ from those that M. Radau set forth in his remarkable account in the *Annuaire du Bureau des Longitudes* for 1903. They have been more or less explicitly pointed out by many astronomers beginning with Lambert who says in his *Lettres cosmologiques*: "The comets lose at each return toward the Sun a little part of their atmosphere * * * This matter may remain in storage, so to speak, until the comet during its revolution comes there to make its new provision of atmosphere, when it goes away from the Sun." (Translation of Darquier, p. 115.)

It will be noted besides that the theory of Kirkwood, which I have tried to state precisely, returns thus into that of capture, relieved of the arbitrary hypothesis of a primitive parabolic orbit.

It seems premature just now to wish to decide between the different theories. But if it were possible, by means of the present power of the spectrographs, to make a detailed analysis of the light of short period comets, these physical data would usefully complete the direct observations. Mr. Barnard has insisted not long since (*Astron. Journal*, No. 246) on the characteristic difference of aspect of the comets of short duration and the comets properly so called. Is there perhaps some difference in their spectra? Then we shall see whether or not the two classes of bodies form parts of the same family.

CURIOUS OPTICAL ILLUSIONS.

ARTHUR K. BARTLETT.

FOR POPULAR ASTRONOMY.

Among the various phenomena of nature that occur unpredicted and unannounced to mankind, there are few more interesting to scientific students, and probably none so deceptive and commonly misunderstood by the general public, as the luminous

colored circles occasionally seen around the Sun, and more frequently around the Moon, known respectively as the solar and lunar halo. These remarkable exhibitions of nature, owing to the complicated appearances they sometimes present, have long engaged the attention of meteorologists, and were, until within a comparatively recent time, extremely difficult to explain. Though more frequently observed in the polar regions, there are probably few persons of mature age, residing in the temperate latitudes, who have not, at some period of their lives, witnessed one or more exhibitions of these curious and beautiful phenomena, which perhaps more than any other manifestations of nature, have engaged the observation of the unscientific world, and attracted multitudes of thinking people to the study of physical science, particularly that fascinating department pertaining to the atmosphere.

There are probably no displays of nature, either in the heavens or the Earth, about which the people are so misinformed, and regarding which so many erroneous notions seem to prevail, as the occurrence of solar and lunar halos, together with the anomalous appearances usually presented by them, though the amount of ignorance relative to these wonderful exhibitions is not surprising when we consider their puzzling nature, and the deceptive features that invariably accompany them, which at one time the wisest philosophers were unable to correctly interpret and explain.

Whenever, under favorable conditions, we observe a luminous circle of the various prismatic colors around the Moon, the sky within the circle being much darker apparently than it is upon the outside, (which is the peculiar feature of a lunar halo) an observer is very naturally led to believe that a ring of light does actually surround the Moon's disk, while inside the ring there is but little, if any, light at all, the sky being dark and unilluminated, and that portion just outside really much brighter, though less bright than the ring itself. Now, it is in this belief that we are deceived by appearances, and that the perplexing nature of a halo is well illustrated; and yet, people will claim, as "seeing is believing," they have an ocular demonstration that a real luminous circle does surround the Moon, and that the dark sky inside receives no light from the Moon's disk, being actually without any illumination, as it appears to be. But paradoxical as it may seem, it is nevertheless a fact, that the sky is really no brighter where the circle of light appears than it is anywhere else around the Moon, and only seems to be for the reason that owing

to the refraction of the Moon's light at an equal distance from her disk, on all sides, more of the luminous rays reach our eyes from the portion of the sky where the circle or ring is seen.

That there is no real luminous circle around the Moon, and that the sky is equally bright where it appears the darkest—the whole appearance being deceptive, as above stated—will be manifest when the cause and nature of the singular phenomenon are fully understood. The late Professor Proctor, explaining similar phenomena in a very interesting and instructive newspaper article entitled "Seeing is Deceiving," well remarked: " 'Seeing is believing,' says the old proverb, but 'seeing is deceiving' would be nearer the mark. We are deceived almost as often, perhaps quite as often as not, by what we see. We are deceived by false impressions even when we know the real state of the case, so that nature may in some sense be compared with a conjurer who explains the trick he is about to play, yet deceives the eye as perfectly as though we knew nothing about the manner of his performance. We know that that handkerchief which we gave him to experiment upon has not been cut in half, yet we saw him cut it in half; we know he has not pounded our gold watch with a mortar, yet that is what we saw him do."

The lunar halo, which by many persons is regarded as a remarkable and unexplained luminosity associated with the Moon, is to meteorological students neither a mysterious nor an anomalous occurrence. It has been frequently observed, and for many years thoroughly understood, and at the present time admits of an easy scientific explanation. It is an atmospheric exhibition due to the refraction and dispersion of the Moon's light through very minute ice-crystals floating at great elevations above the Earth, and is explained by the science of meteorology, to which it properly belongs; for it is not of cosmical origin, and in no way pertains to astronomy, as most persons suppose, except as it depends upon the Moon, whose light, passing through the atmosphere, produces the luminous halo, which, as will be seen, is simply an optical illusion originating, not in the vicinity of the Moon—two hundred and forty thousand miles away—but just above the Earth's surface, and within the aqueous envelope that surrounds it on all sides.

A lunar halo, or circles of prismatic colors seen around the Moon, never occurs except when the sky is somewhat hazy, and presents a dull leaden appearance. Usually only one circle is seen surrounding the Moon, and it is always of large size, being about forty-five degrees in diameter, or eighty times the apparent diam-

eter of the Moon, corresponding to one-half the distance from the zenith to the horizon. The sky within the circle is always apparently much darker than it is for some distance on the outside —a feature which is the peculiar characteristic of a halo when seen under the most favorable conditions—and the circle exhibits the seven prismatic colors seen in the rainbow, the inner edge being red and quite sharply defined, while the other colors are more or less mingled and superposed, so that the outer edge of the circle is nearly white and usually not very clearly defined.

Sometimes a number of large circles are seen around the Moon, presenting a peculiar and very complicated appearance, and they are seldom concentric as in a lunar corona, but intersect each other with mathematical exactness, exhibiting a structure that is often wonderful to behold. A true halo is never produced when the sky is perfectly clear, as a slight haze is essential to its appearance, and the beautiful illusion is visible only under rare and peculiar atmospheric conditions. In connection with a halo, white bands, crosses or arches, are sometimes observed, which also result from the same conditions of the atmosphere at great elevations above the Earth.

A halo may form around the Sun as well as around the Moon, and all the curious features above described are similarly observed; but a halo is most frequently noticed about the Moon for the reason that we are too much dazzled by the Sun's light to distinguish faint colors surrounding its disk, and to see them it is necessary to look through smoked glass or view the Sun by reflection from the surface of still water, by which means its brilliancy is very much reduced. When a halo is seen around the Sun, a white circle passing through the Sun and parallel to the horizon is sometimes observed, which is known to meteorologists as the "parhelic circle," from the fact that parhelia or mock-suns are frequently noticed in connection with it. These productions which are commonly called "sun-dogs," are faint images of that luminary, appearing at one, two or more points in connection with a halo, and at those parts where the circles cross each other, or cut the parhelic circle above mentioned. The number of these mock-suns or parhelia, visible at the same time, is variable; sometimes one or two only are to be seen, at other times four or five, and on some occasions as many as seven have been observed at once. These mock-suns usually appear about the size of the real Sun, but not quite so bright, though on rare occasions they are said to rival their parent luminary in brilliancy and splendor.

Such appearances, which are also seen about the Moon,

(known as mock-moons or "moon-dogs") are most frequently observed in the polar regions, but often occur in the more temperate latitudes, and are produced by the extra light concentrating at those points where the circles intersect, there being at such places a double cause of illumination, presenting the singular spectacle of a faint white disk, resembling that of the Sun or Moon. Parhelia, or mock-suns, are generally red on the side toward the Sun, and they sometimes have a prolongation in the form of a tail, several degrees in length, which coincides in direction with that of the parhelic or horizontal circle. A recent writer on the subject says: "Parhelia have been observed frequently both in ancient and modern times. Aristotle records two appearances of these meteors, and Pliny mentions their occurrence at Rome. A double parhelion, which was noticed before the Christian era, is referred to by St. Augustine. Many others have been observed from different points on the continent. On the 2nd of January, 1586, Christopher Rotham saw, at Cassel, before sun-rise, an upright column of light of the breadth of the Sun's disk. As he rose to view, he was preceded and followed by a parhelion, which appeared in contact with his orb, and continued visible for thirty minutes, and then were hidden by a cloud. On the 28th of February, 1551, mock-suns were seen at Antwerp; and on the 17th of March of the same year, a similar phenomenon, with two halos, was witnessed at the same place. Four days after the last named, two parhelia, with three halos were seen at Madgeberg."

A halo may be produced artificially, and its appearance beautifully illustrated, by crystallizing some salt (such as alum) upon a glass plate, and then looking through the plate at the Sun or a bright light, when the luminous circles above described will be observed. The formation of a circle of light around the Sun or Moon, and the production of the dark circle to which we have referred, may also be illustrated by an interesting imaginary experiment, which is thus described by the late Professor Loomis, an eminent authority on the subject of atmospheric phenomena: "If we conceive a beam of light to be admitted through a small aperture into a dark room, and to fall upon a large number of ice-prisms having angles of sixty degrees, and occupying every possible position, all the incident rays will be deviated from their first direction, but in no case will the deviation be less than about twenty-two degrees. A large number of spectra will be cast upon the opposite wall, but opposite to the aperture through which the light is admitted, there will be a circle of twenty-two degrees

radius upon which no spectrum can fall, and the red end of each spectrum will be turned toward the center of the circle. If the number of the spectra be sufficiently great, they will together form a circle of twenty-two degrees radius, bordered with the red upon the inside; but beyond the red the different colors will be so superposed as to produce a light nearly white. * * * The circle within the halo is much darker than the space without it, because from no part of this circle can a ray of the Sun, refracted by the ice-prisms, reach the eye of the observer."

The halo is less brilliant and beautiful, but far more frequent, than the rainbow. Scarcely a week passes during the whole year in which the exhibition does not occur. In summer the ice-crystals that produce the halo are three or four miles high, above the limit of perpetual frost, and for this reason the apparition is sometimes called the "frost-bow." As the rainbow is sometimes seen in dew-drops on the ground, so the "frost-bow," just after sunrise, has been noticed in the crystals which fringe the grass. A halo is the bright border of an illuminated zone, and Professor Olmsted says: "As in the rainbow, so in the halo, the visible band of colors is only the border of a large illuminated space on the sky. The ordinary halo, therefore, is the bright inner border of a zone, which is more than twenty degrees wide. The whole zone, except the inner edge, is too faint to be generally noticed, though it is perceptibly more luminous than the space between the halo and the luminary."

A corona is an appearance of faintly-colored rings, often seen around the Sun and Moon when a light, fleecy cloud passes over them, and should not be mistaken for a halo, which is much larger and more complicated in its structure, as explained above. These two phenomena are frequently confounded by inexperienced observers, but they exhibit peculiar features by which each may be easily distinguished from the other. Both exhibit the seven prismatic colors, but in a corona the colors are reversed, the red being on the outer edge instead of on the inner edge, as in a halo; and the circles of a corona, besides being smaller, are concentric with each other—the inner one being small, the diameter of the second being double, and that of the third treble, the diameter of the first. The structure of the corona is quite simple, and never exhibits the attractive features observed in the halo, which is a production of comparatively rare occurrence, while a corona may be seen every time a light, transparent cloud comes between us and the Sun or Moon, and is produced by the diffraction of light passing between the minute globules of condensed vapor in a

cloud.

What we have said regarding the size of a halo, will alone enable an observer to recognize this phenomenon and distinguish it from a corona. Professor Loomis says: "The mean of eighty-three measurements of the radius of the red circle of a halo is 21 degrees 36 minutes, which is almost identical with the radius computed from theory." The diameter of the luminous circles of a corona is not always the same, and while they are never large, the diameter of the first red ring varies from three degrees to six degrees, and that of the second red ring from five degrees to ten degrees.

A corona, like a halo, may be easily produced artificially. If we sprinkle upon a pane of glass a small quantity of lycopodium, or any very fine dust of nearly uniform fineness, and then look at the Moon through this glass, we shall see it surrounded by luminous rings of prismatic colors, precisely like those that are formed by a cloud; and if on a cold winter evening, we breathe upon a pane of glass, the breath will condense into very small globules and freeze. If we look at the Moon, or even at a street lamp, through this glass, we shall see a similar system of colored rings, having violet on the inside.

More solar and lunar halos are usually seen in winter than in summer, owing to the favorable conditions of the former season for the formation of ice-crystals in the upper regions of the atmosphere, upon the existence of which such illusions depend for their production, and the singular appearances they present. During the cold weather that prevailed in the winter of 1887-8, the frosty condition of the atmosphere was particularly favorable for the production of these curious displays, and many exhibitions of the kind were observed in various portions of the country where such appearances are uncommon, and have seldom, if ever, occurred before. Many reports of such luminous circles appeared in the newspapers at that time, some of the exhibitions having been unusually interesting and remarkable, but none of the accounts seen by the writer—with one or two exceptions—explained the phenomena correctly, or mentioned their real nature, which was evidently not known or misunderstood by those who described them. On the evening of March 30th, 1890, a beautiful lunar halo, accompanied by a "moon-dog," was observed by the writer, and on the following morning a brilliant solar halo, with two "sun-dogs," appeared about one hour after sunrise, which attracted great attention from those who were fortunate enough to witness the interesting exhibition.

In January, 1888, a leading metropolitan newspaper published the following account, which illustrates the deceptive nature of such appearances, and the erroneous ideas regarding them: "Yesterday, shortly before noon, the Sun shone through a heavy bank of dull clouds. On each side were two lesser luminaries, scarcely less bright than the Sun, and about the same altitude as it. Well up toward the zenith appeared two rainbows, joined like two C's placed back to back. These were not brilliant, but were clear and distinct. High above these rose two more rainbows, placed in a like manner, the colors mingling in the most harmonious blending at the junction. These two were brilliant, and the ends of each bow were as even as if cut off with a knife. At the right of the upper bow was another equally brilliant bow standing alone. This lasted several minutes, and was seen by a great number of people." Now, the "two lesser luminaries" mentioned by the writer of the above, were really not "luminaries" at all, but simply parhelia or mock-suns, the nature of which we have already explained; and the "two rainbows" were doubtless portions of an incomplete circle, or the curious arches to which we have referred, the whole representation constituting a typical solar halo, which is exceedingly rare in this portion of the country. The reference to a "rainbow" in connection with the exhibition described, is certainly amusing, and it is perhaps unnecessary to state that a rainbow, though exhibiting the prismatic colors seen in a halo, is never observed in the immediate vicinity of the Sun, but always in the opposite part of the heavens, and is never produced except when rain is actually falling from the clouds.

Of all the numerous weather proverbs current among the people, those relating to the production of a halo should be included with the few for which there is considerable scientific foundation, justified by actual experience and observation. There is perhaps no better known, or more popular weather prognostic than that pertaining to the lunar halo, which has long been recognized, even among scientific persons, as an almost unfailing sign of foul weather, and reliable indication of an approaching storm. One of the old familiar proverbs relating to the lunar halo is expressed in the lines:

"When round the Moon there is a brugh
The weather will be cold and rough."

Professor John Westwood Oliver, in a recent article on "The Moon and the Weather," published in Longman's magazine, says: "The halo is an old sign of bad weather. Of sixty-one lunar

halos observed in the neighborhood of London, thirty-four were followed by rain within twenty-four hours, nineteen by rain within four days, and only eight by no rain at all." As a halo is never seen except when the sky is hazy, it indicates that moisture is accumulating in the atmosphere, which will form clouds, and usually result in a storm. But the popular notion that the number of bright stars visible within the circle indicates the number of days before the storm will occur, is without any foundation whatever, and the belief is almost too absurd to be refuted. In whatever part of the sky a lunar halo is seen, one or more bright stars are always sure to be noticed inside the luminous ring, and the number visible depends entirely upon the position of the Moon. Moreover, when the sky within the circle is examined with even a small telescope, hundreds of stars are visible where only one, or perhaps two or three, were perceived by the naked eye.

A lunar halo, when seen under favorable conditions, with all the curious features that usually accompany it, is one of the most interesting and beautiful exhibitions of nature; and there are many remarkable facts connected with its formation and appearance that can not be dealt with in a popular description of the phenomenon, but which are fully explained in nearly every work on natural philosophy, meteorology or physical geography. In Professor Loomis' "Treatise on Meteorology" may be found a clear and exhaustive description of halos and coronas, fully illustrated and scientifically explained. There is an instructive popular article entitled "The Lunar Halo," by the late Professor Proctor, in his admirable work "Flowers of the Sky," which contains an excellent engraving illustrating the one-ring halo, most commonly observed, and showing the dark space around the Moon, which is always noticed in a perfect halo, and is thoroughly explained in the above mentioned work, together with many other paradoxical features and curious illusions, associated with the wonderful atmospheric spectacle.

BATTLE CREEK, Mich.

MEASURES OF THE RINGS OF SATURN.

F. E. SEAGRAVE.

FOR POPULAR ASTRONOMY.

The enclosed measures of Saturn's rings were made here from August 18th to November 9th, 1903. The planet was examined on about forty nights from the middle of June to

the middle of November. There were only ten nights out of the forty that were called good, and only three (3) where the seeing was excellent. These measures were made to still further test Struve's theory that the Saturnian Ring system has undergone since the epoch of its discovery great and surprising changes. M. Struve claimed after making a series of measures at Pulkova in the years 1850 and 1851, and comparing them with those of other astronomers taken on previous occasions, that the outer diameter of the Ring System remained constant while the inner diameter was gradually decreasing at the rate of about 1″.25 per century. A decrease large enough to bring the inner edge of the inner bright ring into contact with the ball about the year 2155. The investigations of M. Struve depended largely upon

MEASURES OF COMBINED WIDTH OF RINGS A, B AND CASSINI DIVISION.

Preceding Side.

75° Merid.	Time.	Microm. Rev.	Sets.	Result.	Seeing.
1903	h m			″	
Aug. 18	8 45	0.627	3	7.281	Good.
Sept. 6	8 15	0.587	3	6.937	"
8	9 00	0.590	4	6 989	"
12	8 00	0.595	4	7.082	"
26	8 30	0.591	3	7.175	Excellent.
Oct. 19	6 0	0.547	3	6.894	Good.
22	5 30	0.548	3	6.941	Excellent.
31	5 40	0.540	2	6 944	"
Nov. 3	5 15	0.538	3	9.952	Good.
9	5 00	0.530	2	6.916	"
		Mean		7.011	

Following Side.

75° Merid.	Time.	Microm. Rev.	Sets.	Result.	Seeing.
1903	h m				
Aug. 18	9 15	0.597	3	6.935	Good.
Sept. 6	8 45	0.582	3	6.878	"
8	9 30	0.589	4	6.977	"
12	8 30	0.581	4	6.917	"
26	9 00	0.578	3	7.018	Excellent
Oct. 19	6 30	0.542	3	6.832	Good.
22	6 00	0.540	3	6.841	Excellent.
31	6 10	0.535	2	6.880	"
Nov. 3	5 45	0.534	3	6.901	Good.
9	5 30	0.534	2	6.968	"
			Mean	6.915	

the observations and measures of the astronomers of from 200 to 250 years ago, and made with very inferior telescopes. In the years 1881 and 1882 M. Struve made a further set of measures to test this, when the planet was situated in nearly the same part of its orbit. These measures did not verify the annual approach of 0″.012. The approach from 1851 to 1882 or for a period of thirty-one years was only 0″.04 instead of 0″.4. The results of my measures taken here on ten nights from August

18th to November 9 show that the combined width of the two bright rings and the Cassini division on the preceding side is 7″.011, and on the following side 6″.915. The distance from the inner edge of the inner bright ring to the limb of the ball on the preceding side measures 3″.661, and on the following side measures 3″.837. The ratio here of the space to the ring on the preceding side is 0.522, and on the following side is 0.554. Comparing these results with those of standard observers taken during the past 75 or 80 years show *no* constant decrease in the ratio (space to ring), and it seems to me as I stated nearly a year ago that Struve's theory should be abandoned on this account. Below are the ratios of the space to the ring from the results of different observers within the past 75 or 80 years.

DISTANCE FROM INNER EDGE OF RING B TO LIMB OF BALL.

Preceding Side.

75° Merid.	Time.	Microm. Rev.	Sets.	Result.	Seeing.
1903	h m			″	
Aug. 18	9 45	0.296	3	3.466	Good.
Sept. 6	9 15	0.304	3	3.628	"
8	10 00	0.311	4	3.719	"
12	9 00	0.317	4	3.791	"
26	9 30	0.308	3	3.758	Excellent.
Oct. 19	7 00	0.288	3	3.649	Good.
22	6 30	0.284	3	3·617	Excellent.
31	6 40	0.288	2	3.722	"
Nov. 3	6 15	0.279	3	3.625	Good.
9	6 0	0.277	2	3.634	"
			Mean	3.661	

Following Side.

75° Merid.	Time.	Microm. Rev.	Sets.	Result.	Seeing.
1903	h m				
Aug. 18	10 15	0.305	3	3.562	Good.
Sept. 6	9 35	0.324	3	3.847	"
8	10 30	0.318	4	3.785	"
12	9 30	0.327	4	3.910	"
26	10 00	0.320	3	3.903	Excellent.
Oct. 19	7 30	0.305	3	3.862	Good.
22	7 00	0.305	3	3.881	Excellent.
31	7 10	0.309	2	3.991	"
Nov. 3	6 45	0.293	3	3.805	Good.
9	6 30	0.292	2	3.828	"
			Mean	3.837	

Ratio of space to ring $\begin{cases}\text{Preceding side } 0.5222\\ \text{Following side } 0.5549\end{cases}$

The measures were made with an 8¼-inch telescope and power 312.

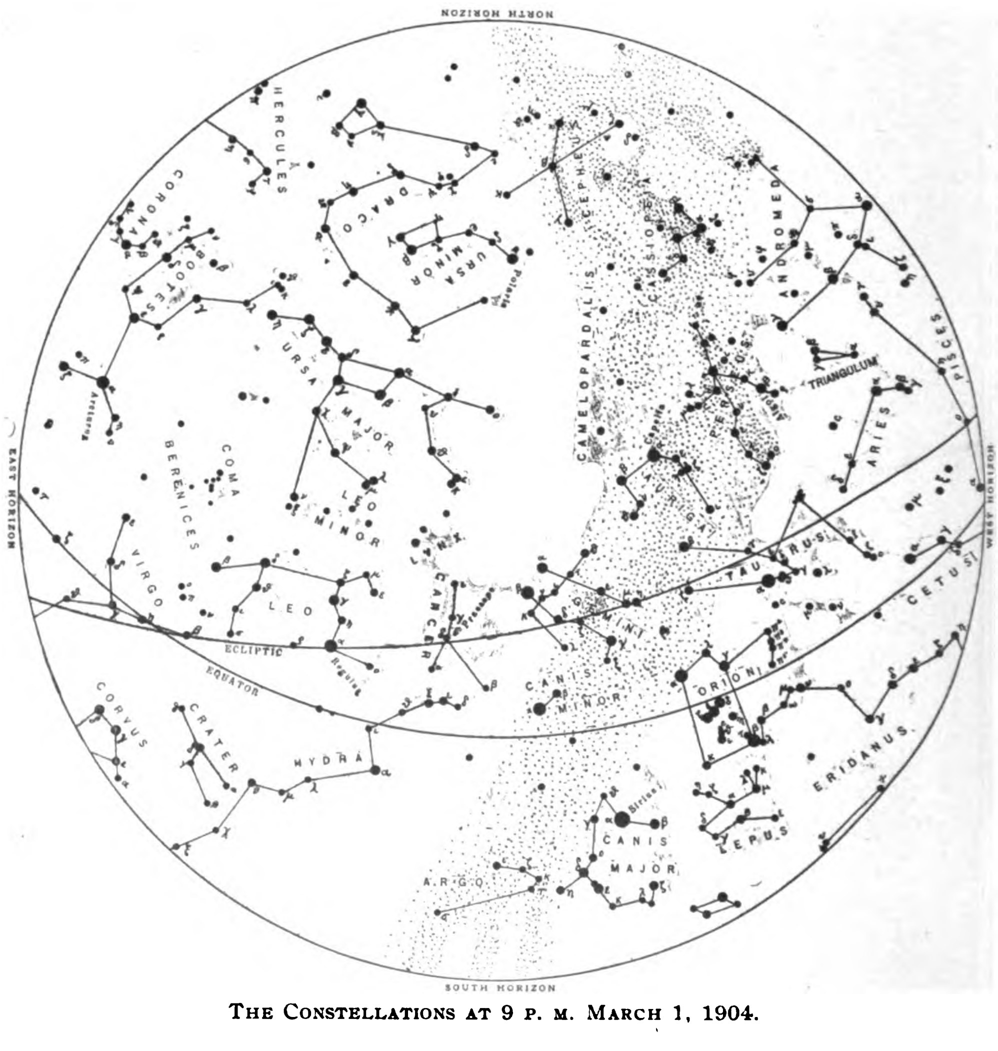
		Space / Ring			Space / Ring
1826	W. Struve	0.65	1880	Meyer	0.62
1837	Encke	0.67	1882	O. Struve	0.48
1838	Galle	0.65	1885	Hall	0.55
1851	O. Struve	0.49	1894	Barnard	0.53
1855	Secchi	0.53	1895	Dyson	0.46
1856	Jacob	0.60	1901	See	0.56

The white spots discovered on the ball by Professor Barnard, and observed by him and other astronomers during the past summer were *not* seen here at any time, even with the best seeing; and using all powers from 150 to 525.

PLANET NOTES FOR MARCH.

H. C. WILSON.

Mercury during March will be invisible to the eye, being on the farther side of the Sun. Superior conjunction will occur March 26.



THE CONSTELLATIONS AT 9 P. M. MARCH 1, 1904.

Venus is morning star, seen as the most brilliant star in the southeastern sky an hour before sunrise. It is only one-third as bright now as in the early part of this winter. The phase of Venus is now gibbous, approaching the full phase.

Mars has caught up with Jupiter in his eastward movement and during March will advance about 20° to the eastward of the latter along the ecliptic. Both planets will during this month be well behind the Sun, although they will be visible shortly after sunset during the first days.

Jupiter comes to conjunction with the Sun March 27 at 4 A. M., central standard time, thirteen hours after Mercury and the two planets will be in conjunction with each other on Mar. 26 at 8 P. M.

Saturn has come out from behind the Sun far enough to be in conjunction with Venus March 7 at 9 P. M. The two planets cannot be seen from America at that time but on the preceding and following mornings they will be seen quite near together.

Uranus will be at quadrature, 90° west from the Sun March 20, and so may be observed in the morning. The planet is to be found with the aid of a telescope among the faint stars between Sagittarius and Scorpio as shown on our chart in the January number.

Neptune will be at quadrature, 90° east from the Sun, March 23 at 11^h P. M It will be at the stationary point (west end of the loop) of its apparent path March 14. Its motion during the month will be very slow, the position being about midway between the bright stars η and μ Geminorum and 11′ south of the line joining those stars.

The Moon.

Phases. 1904		Rises. h m	Sets. (Central Standard Time at Northfield Local Time 13m less.) h m
Mar. 1-2	Full Moon	5 50 P. M.	7 02 A. M.
8	Last Quarter	12 51 A. M.	10 57 P. M.
16	New Moon	6 07 "	6 02 "
24-25	First Quarter	10 54 "	1 59 A. M.
30-31	Full Moon	5 54 P. M.	6 05 "

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Mar. 6	η Libræ	5.5	13	06	86	14	14	311	1	08
7	24 Scorpii	5.2	15	08	78	16	24	309	1	16
9	B.A.C. 6287	6.0	17	11	75	18	39	286	1	28
10	ρ^1 Sagittarii	3.9	17	33	76	19	01	276	1	28
22	B.A.C. 1406	7.5	7	00	154	7	28	196	0	28
22	α Tauri	1.0	8	00	106	9	06	249	1	06
24	20 Geminorum	6.3	9	40	34	10	10	343	0	30
24	21 Geminorum	6.5	9	42	31	10	9	346	0	27
26	29 Cancri	5.9	8	21	119	9	39	275	1	18
27	o Leonis	3.8	15	21	94	16	10	300	0	49

Annular Eclipse of the Sun.—On March 16 from 14^h 36^m to 20^h 45^m Green wich Mean Time there will occur an annular eclipse of the Sun, visible as a partial eclipse in the eastern part of Africa, the Indian Ocean, the southern part of Asia, Japan and the islands between Japan and Australia. A diagram showing the regions covered by the eclipse was given in our last number.

COMET AND ASTEROID NOTES.

Ephemeris of Encke's Comet.—Mr. F. E. Seagrave sends us an ephemeris of Encke's Periodic comet computed by himself from the following elements. These have not been corrected for perturbations and so may be considerably in error on that account.

ELEMENTS.

Epoch and osculation July 8.0, 1901 Berlin M. T.

$M = 339° \; 16' \; 15''.38$	$\mu = 1073''.875$
$\pi = 158 \; 47 \; 57 .37$	$\log a = 0.3460351$
$\Omega = 334 \; 48 \; 58 .06$	$\log q = 9.5335591$
$i = 12 \; 53 \; 38 .46$	$\log Aph = 0.6122665$
$\phi = 57 \; 46 \; 44 .82$	$P = 1206^d \; 20^h \; 13^m \; 55^s.2$

This comet is due to reach perihelion Jan. 4th, 1905. It should be visible towards the latter part of next September. The eccentricity of the orbit is considerable. So much so that the comet will describe a heliocentric arc of 234° in a period of only 116 days, or from Oct. 4th, 1904 to Jan. 28th, 1905. It will however take it 1090.8 days to describe the remaining 126°. The length of the orbit is about double its breadth. The periodic time has decreased 5 days 22½ hours since the year 1789.

EPHEMERIS OF ENCKE'S COMET.

Greenwich Midnight.	α			δ			log r	log Δ
1904	h	m	s	°	′	″		
Oct. 4	1	27	18	+31	57	39	0.230488	9.879192
8	1	15	41	32	40	13	0.217646	9.843552
12	1	1	39	33	16	12	0.204121	9.807584
16	0	44	59	33	41	54	0.189848	9.771744
20	0	25	31	33	52	32	0.174749	9.736626
24	0	3	17	33	42	26	0.158738	9.702975
28	23	38	34	33	5	33	0.141712	9.671671
Nov. 1	23	11	52	31	56	39	0.123552	9.643658
5	22	44	0	30	12	44	0.104119	9.619824
9	22	15	51	27	54	17	0.083246	9.600824
13	21	48	12	25	5	14	0.060735	9.586951
17	21	21	32	21	51	45	0.036349	9.578144
21	20	56	3	18	20	23	0.009797	9.574098
25	20	31	41	14	36	38	9.980731	9.574448
29	20	8	8	10	44	8	9.948720	9.578978
Dec. 3	19	45	4	6	44	48	9.913241	9.587793
7	19	22	8	+2	39	27	9.873672	9.601484
11	18	59	9	−1	31	6	9.829299	9.621208
15	18	36	18	5	44	36	9.779417	9.648623
19	18	14	20	9	56	11	9.723657	9.685527
23	17	54	45	13	58	37	9.662926	9.733189
27	17	39	56	17	43	40	9.601753	9.791418
31	17	32	44	21	3	13	9.552224	9.857408
1905								
Jan. 4	17	35	14	23	48	38	9.533615	9.925048
8	17	46	43	25	52	16	9.556166	9.986970
12	18	3	42	27	13	26	9.607696	0.039121
16	18	22	43	27	59	11	9.669216	0.081759
20	18	41	45	−28	18	46	9.729561	0.116852

Nearest Earth Nov. 21, 1904. In perihelion Jan. 4, 1905.

F. E. SEAGRAVE.

Ephemeris of Winnecke's Comet.—In *A. N.* 3916 Mr. C. Hillebrand continues his ephemeris of Winnecke's comet to April 1. In all this time however the comet is on the farther side of the Sun and so near the line joining Earth and Sun that the only possibility of observing it will be in the bright twilight just before sunrise. There is very little hope of its being detected.

EPHEMERIS OF WINNECKE'S COMET.

Berlin M. T. 1904.	α App. h	m	s	δ App. °	′	″	log. *r*.	log Δ.
Feb. 1	20	14	47.17	−20	46	57.1	9.972633	0.276601
3		24	49.57	20	38	55.9		
5		34	45.89	20	28	49.3	9.978474	0.280344
7		44	35.45	20	16	41.5		
9		54	17.77	20	2	38.9	9.985794	0.284645
11	21	3	52.26	19	46	47.2		
13		13	18.57	19	29	13.3	9.994414	0.289439
15		22	36.23	19	10	3.8		
17		31	45.02	18	49	25.7	0.004129	0.294662
19		40	44.62	18	27	25.9		
21		49	34.89	18	4	11.3	0.014739	0.300253
23	21	58	15.57	17	39	49.1		
25	22	6	46.71	17	14	25.9	0.026059	0.306155
27		15	8.24	16	48	8.4		
29		23	20.23	16	21	2.8	0.037913	0.312312
Mar. 2		31	22.67	15	53	15.7		
4		39	15.70	15	24	52.5	0.050148	0.318669
6		46	59.37	14	55	59.0		
8		54	33.89	14	26	40.6	0.062629	0.325168
10	23	1	59.41	13	57	2.8		
12		9	16.11	13	27	9.8	0.075244	0.331755
14		16	24.18	12	57	6.7		
16		23	23.75	12	26	57.1	0.087896	0.338374
18		30	15.02	11	56	45.6		
20		36	58.19	11	26	35.4	0.100509	0.344983
22		43	33.48	10	56	30.4		
24		50	1.11	10	26	33.2	0.113024	0.351541
26		56	21.23	9	56	46.7		
28	0	2	34.25	0	27	13.4	0.125392	0.358013
30		8	40.19	8	57	55.6		
Apr. 1	0	14	39.33	− 8	28	54.1	0.137572	0.364369

New Elements of Planet (470) Kilia.—In *A. N.* 3917 Mr. H. Kreutz gives the following elements of this asteroid, depending upon four observations in 1901 and five in 1902:

	Epoch 1901 April .90	1902 Oct. 21.0 Berlin
$M =$	350° 42′ 58″.3	138° 56′ 09″.4
$\omega =$	43 59 37 .5	43 50 52 .8
$\Omega =$	173 10 49 .4	173 07 36 .1
$i =$	7 13 21 .3	7 13 40 .2
$\phi =$	5 26 15 .2	5 29 58 .5
$\mu =$	952″.3160	952″.3542
$\log a =$	0.380817	0.380805

The planet was observed in 1902 as (489) [1902 JO] but the identity is clearly proved by representation of the observations by the above elements which have been corrected for the perturbations by the planet Jupiter.

Asteroid Iris (7) Variable.—A telegram from Professor E. C. Pickering announces that Wendell of Harvard College Observatory finds the asteroid Iris to be variable, with a period of six hours and range of variation of ¼ magnitude

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with noon. The hours from 12 to 24 are those which occur in the night in the United States. To obtain Eastern Standard time subtract 5 hours; for Central Standard time subtract 6 hours, etc.]

U Cephei.

	d	h
Mar	3	2
	5	14
	8	2
	10	14
	13	2
	15	13
	18	1
	20	13
	23	1
	25	13
	28	0
	30	12

Z Persei

Mar.	4	14
	7	16
	10	17
	13	19
	16	20
	19	21
	22	23
	26	0
	29	1

Algol.

Mar.	1	4
	4	1
	6	22
	9	18
	12	15
	15	12
	18	9
	21	6
	24	3
	26	23
	29	20

λ Tauri.

Mar.	1	21
	5	20
	9	19
	13	17
	17	16
	21	15
	25	14
	29	13

R Canis Maj.

Mar.	1	18
	2	21
	4	0
	5	4
	6	7
	7	10
	8	13
	9	17
	10	20

R Canis Maj.

	d	h
Mar.	11	23
	13	2
	14	6
	15	9
	16	12
	17	15
	18	19
	19	22
	21	1
	22	4
	23	8
	24	11
	25	14
	26	18
	27	21
	29	0
	30	3
	31	7

RR Puppis

Mar.	5	19
	12	6
	18	16
	25	2
	31	12

V Puppis.

Mar.	1	3
	2	14
	4	1
	5	12
	6	23
	8	10
	9	21
	11	8
	12	19
	14	6
	15	16
	17	3
	18	14
	20	1
	21	12
	22	23
	24	10
	25	21
	27	8
	28	19
	30	5
	31	16

S Cancri

Mar.	5	21
	15	8
	24	20

S Antliæ.

	d	h
Mar.	1	13
	2	13
	3	12
	4	11
	5	10
	6	10
	7	9
	8	9
	9	8
	10	7
	11	7
	12	6
	13	5
	14	5
	15	4
	16	3
	17	3
	18	2
	19	1
	20	1
	21	0
	21	23
	22	23
	23	22
	24	21
	25	21
	26	20
	27	19
	28	19
	29	18
	30	17
	31	17

S Velorum.

Mar.	6	2
	12	0
	17	23
	23	21
	29	20

W. Urs. Maj.

Period $4^h\ 0^m.2$

Mar. 1-10 11^h

Mar. 11-31 12^h

RR Velorum.

Mar.	2	4
	4	0
	5	21
	7	17
	9	14
	11	10
	13	7

RR Velorum.

	d	h
Mar.	15	3
	17	0
	18	20
	20	17
	22	13
	24	10
	26	6
	28	3
	29	23
	31	20

Z Draconis.

Mar.	3	22
	5	6
	6	15
	7	28
	9	8
	10	17
	12	1
	13	10
	14	18
	16	3
	17	12
	18	20
	20	5
	21	13
	22	22
	24	6
	25	15
	27	0
	28	8
	29	17
	31	1

δ Librae.

Mar.	2	22
	5	6
	7	13
	9	21
	12	5
	14	13
	16	21
	19	5
	21	13
	23	20
	26	4
	28	13
	30	21

U Coronae.

Mar.	4	7
	7	17
	11	4
	14	15
	18	2

U Coronae.

	d	h
Mar.	21	13
	25	0
	28	11
	31	21

U Ophiuchi.

Mar.	1	10
	2	6
	3	2
	3	22
	4	19
	5	15
	6	11
	7	7
	8	3
	8	23
	9	19
	10	15
	11	12
	12	8
	13	4
	14	0
	14	20
	15	16
	16	12
	17	9
	18	5
	19	1
	19	21
	20	17
	21	13
	22	9
	23	5
	24	2
	24	22
	25	18
	26	14
	27	10
	28	6
	29	2
	29	22
	30	19
	31	15

R Aræ.

Mar.	3	3
	7	13
	11	23
	16	10
	20	20
	25	6
	29	16

Minima of Variable Stars of the Algol Type.—Continued.

Z Herculis.

	d	h
Mar.	4	2
	5	23
	8	2
	9	23
	12	2
	13	23
	16	2
	17	23
	20	1
	21	22
	24	1
	25	22
	28	1
	29	22

RS Sagittarii.

	d	h
Mar.	2	13
	4	23
	7	9
	9	19
	12	5
	14	15
	17	1
	19	11
	21	21
	24	7
	26	17
	29	3
	31	13

RX Herculis.

	d	h
Mar.	1	15
	2	12
	3	9
	4	7

RX Herculis.

	d	h
Mar.	5	4
	6	1
	6	23
	7	20
	8	17
	9	15
	10	12
	11	9
	12	7
	13	4
	14	1
	14	23
	15	20
	16	17
	17	15
	18	12
	19	9
	20	7
	21	4
	22	2
	22	23
	23	20
	24	18
	25	15
	26	12
	27	10
	28	7
	29	4
	30	2
	30	23
	31	20

RV Lyræ.

	d	h
Mar.	3	12
	7	3
	10	17

RV Lyrae.

	d	h
	14	7
	17	22
	21	12
	25	3
	28	17

U Sagittæ.

	d	h
Mar.	2	5
	5	14
	8	23
	12	8
	15	17
	19	3
	22	12
	25	21
	29	6

SY Cygni.

	d	h
Mar.	2	15
	8	16
	14	16
	20	16
	26	16

SW Cygni.

	d	h
Mar.	3	1
	7	15
	16	18
	21	8
	25	22
	30	11

WW Cygni.

	d	h
Mar.	2	23
	4	10
	7	21
	12	8

WW Cygni.

	d	h
	15	19
	19	5
	22	16
	26	3
	29	14

W Delphini.

	d	h
Mar.	4	13
	9	8
	14	3
	18	23
	23	13
	28	13

VV Cygni.

	d	h
Mar.	2	9
	3	21
	5	8
	6	20
	8	7
	9	19
	11	6
	12	17
	14	5
	15	16
	17	4
	18	15
	20	3
	21	14
	23	2
	24	13
	26	1
	27	12
	28	23
	30	11
	31	22

VW Cygni.

	d	h
Mar.	2	13
	11	0
	19	10
	27	20

Y Cygni.

	d	h
Mar.	1	5
	2	19
	4	5
	5	19
	7	4
	8	19
	10	4
	11	19
	13	4
	14	19
	16	4
	17	19
	19	4
	20	19
	22	4
	23	19
	25	4
	26	18
	28	4
	29	18
	31	4

UZ Cygni.

	d	h
Mar.	17	14

Maxima of UY Cygni.

Period $13^h\ 27^m\ 21^s$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Mar.	1	7	Mar.	9	3	Mar.	16	23	Mar.	24	20
	2	9		10	6		18	2		25	22
	3	12		11	9		19	5		27	1
	4	15		12	12		20	8		28	4
	5	18		13	15		21	11		29	7
	6	21		14	17		22	14		30	10
	8	0		15	20		23	17			

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
Mar.	1	10	Mar.	9	11	Mar.	17	12	Mar.	25	13
	2	10		10	11		18	12		26	13
	3	10		11	11		19	12		27	13
	4	10		12	11		20	12		28	13
	5	11		13	12		21	13		29	13
	6	11		14	12		22	13		30	13
	7	11		15	12		23	13		31	13
	8	11		16	12		24	13			

Variable Stars of Short Period not of the Algol Type.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
T Crucis	Mar. 1	0	Mar. 3	1	W Sagittarii	Mar. 14	17	Mar. 17	17
Y Sagittarii	1	1	2	20	SU Cygni	15	2	16	10
T Vulpeculae	1	16	5	2	ζ Geminorum	15	7	20	7
S Sagittæ	1	18	2	17	S Normae	16	5	20	15
V Velorum	1	21	5	8	δ Cephei	16	13	17	22
S Muscae	1	22	8	3	V Centauri	16	21	18	8
X Cygni	1	4	2	13	T Velorum	16	23	18	8
T Velorum	3	1	4	10	U Sagittarii	17	17	20	16
κ Pavonis	3	11	7	6	V Carinae	17	19	19	23
SU Cygni	3	13	4	21	S Triang.Austr.	17	20	19	22
U Sagittarii	4	5	7	4	R Crucis	17	23	19	8
U Vulpeculae	4	7	6	10	X Cygni	18	7	24	12
V Carinae	4	9	6	11	Y Sagittarii	18	8	20	3
S Crucis	4	23	6	11	RV Scorpii	18	9	19	19
ζ Geminorum	5	3	10	3	S Sagittae	18	11	21	21
S. Triang. Austr.	5	4	7	6	β Lyrae	18	17	22	0
T Vulpeculae	5	15	7	0	SU Cygni	18	22	20	6
X Sagittarii	5	15	8	12	T Vulpeculae	18	22	20	13
δ Cephei	5	19	7	4	S Crucis	19	1	20	7
U Aquilae	5	19	7	23	V Velorum	19	6	20	5
β Lyræ	5	19	9	2	X Sagittarrii	19	16	22	13
V Centauri	5	21	7	8	U Aquilae	19	20	22	0
V Velorum	6	3	7	2	U Vulpeculae	20	6	22	9
RV Scorpii	6	6	7	16	S Muscae	21	5	24	16
R Crucis	6	7	7	16	T Crucis	21	11	23	12
S Normae	6	11	10	21	T Velorum	21	14	22	23
Y Ophiuchi	6	12	9	3	κ Pavonis	21	16	25	11
W Geminorum	6	11	12	16	η Aquilae	21	18	24	3
Y Sagittarii	6	19	8	14	δ Cephei	21	22	23	7
W Sagittarii	7	2	10	2	W Geminorum	22	0	24	15
SU Cygni	7	9	8	17	W Sagittarii	22	7	25	7
η Aquilae	7	16	9	1	V Centauri	22	9	23	20
T Velorum	7	17	9	18	SU Cygni	22	18	24	2
T Crucis	7	9	9	18	T Vulpeculae	23	9	24	18
S Crucis	9	16	11	4	Y Ophiuchi	23	13	24	18
T Vulpeculae	10	1	11	10	V Velorum	23	15	29	14
S Sagittae	10	1	13	11	R Crucis	23	18	25	3
V Velorum	10	12	11	11	S Crucis	23	18	25	6
U Sagittarii	10	23	13	22	S Triang. Austr.	24	4	26	6
V Carinae	11	3	13	7	V Carinae	24	12	26	16
δ Cephei	11	4	12	13	Y Sagittarii	24	4	25	23
SU Cygni	11	6	12	14	RV Scorpii	24	10	25	20
V Centauri	11	9	12	20	U Sagittarii	24	11	27	10
W Virginis	11	12	—	—	β Lyrae	25	4	28	6
S Trianguli Austr.	11	12	13	5	ζ Geminorum	25	10	30	10
S Muscae	11	13	15	1	S Normae	25	23	30	9
R Crucis	12	3	13	12	T Velorum	26	6	27	15
U Vulpeculae	12	6	14	9	SU Cygni	26	15	27	23
β Lyrae	12	6	15	8	X Sagittarii	26	16	23	13
TX Cygni	12	7	17	10	U Aquilae	26	20	29	0
T Velorum	12	7	13	16	S Sagittae	26	20	30	6
RV Scorpii	12	7	13	17	TX Cygni	27	1	32	4
κ Pavonis	12	13	16	8	δ Cephei	27	6	28	15
Y Sagittarii	12	14	14	9	T Vulpeculae	27	19	29	4
X Sagittarii	12	15	15	12	T Monocerotis	27	20	35	18
U Aquilae	12	19	14	23	V Centauri	27	21	29	8
V Velorum	13	21	14	20	T Crucis	27	22	29	23
W Geminorum	14	6	16	21	V Velorum	27	23	28	22
S Crucis	14	9	15	21	U Vulpeculae	28	5	30	8
T Crucis	14	12	15	21	S Crucis	28	10	29	22
T Vulpeculae	14	11	16	12	W Virginis	28	18	——	
η Aquilae	14	13	16	22	η Aquilae	28	22	31	7

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
R Crucis	Mar. 29	14	30	23	κ Pavonis	Mar. 30	21	32	6
W Geminorum	29	18	32	9	T Velorum	30	21	34	8
W Sagittarii	29	21	32	21	S Muscae	30	18	34	13
Y Sagittarii	29	22	31	17	T^3 Cygni	30	23	32	7
S Triang. Austr.	30	11	32	13	U Sagittarii	31	4	34	3
RV Scorpii	30	12	31	22	β Lyrae	31	15	34	22

Approximate Magnitudes of Variable Stars Jan. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn
T Androm.	0	17.2	+26	26	*f*	R Camel.	14	25.1	+84	17	11*d*
T Cassiop.	0	17.8	+55	14	8*i*	R Bootis	14	32.8	+27	10	*f*
R Androm.	0	18.8	+38	1	8*i*	S Librae	15	15.6	−20	2	*u*
S Ceti	0	19.0	− 9	53	12*d*	S Serpentis	15	17.0	+14	40	*f*
W Cassiop.	0	49.0	+58	1	*u*	S Coronae	15	17.3	+31	44	10*i*
S "	1	12.3	+72	5	13*d*	S Urs. Min.	15	33.4	+78	58	7
R Piscium	1	25.5	+ 2	22	12*d*	R Coronae	15	44.4	+28	28	6
R Trianguli	1	31.0	+33	50	7*d*	V "	15	45.9	+39	52	*u*
U Persei	1	52.9	+54	20	8*d*	R Serpentis	15	46.1	+15	26	*u*
R Arietis	2	10.4	+24	36	8	R Herculis	16	1.7	+18	38	9*d*
o Ceti	2	14.3	− 3	26	8*i*	R Scorpii	16	11.7	−22	42	*s*
S Persei	2	15.7	+58	8	10*d*	S "	16	11.7	−22	39	*s*
R Ceti	2	20.9	− 0	38	13*d*	U Herculis	16	21.4	+19	7	*u*
U "	2	28.9	−13	35	13*d*	R Ursae Min.	16	31.3	+72	28	*u*
R Persei	3	23.7	+35	20	*u*	W Herculis	16	31.7	+37	32	9*i*
R Tauri	4	22.8	+ 9	56	9*i*	R Draconis	16	32.4	+66	58	*u*
S "	4	23.7	+ 9	44	15*f*	S Herculis	16	47.4	+15	7	9*d*
R Aurigæ	5	9.2	+53	28	8*i*	R Ophiuchi	17	2.0	−15	58	9*d*
U Orionis	5	49.9	+20	10	12*d*	T Herculis	18	5.3	+31	0	10*d*
R Lyncis	6	53.0	+55	28	10*d*	R Scuti	18	42.2	− 5	49	*s*
R Gemin.	7	1.3	+22	52	11*d*	R Aquilae	19	1.6	+ 8	5	*u*
S Canis Min.	7	27.3	+ 8	32	8*i*	R Sagittarii	19	10.8	−19	29	*s*
R Cancri	8	11.0	+12	2	9*d*	S "	19	13.6	−19	12	*s*
V "	8	16.0	+17	36	12*i*	R Cygni	19	34.1	+49	58	9*d*
S Hydrae	8	48.4	+ 3	27	8*i*	RT "	19	40.8	+48	32	*f*
T "	8	50.8	− 8	46	9*i*	X "	19	46.7	+32	40	7*d*
R Leo. Min.	9	39.6	+34	58	9*d*	S Cygni	20	3.4	+57	42	*f*
R Leonis	9	42.2	+11	54	9*d*	RS "	20	9.8	+38	28	7
R Urs. Maj.	10	37.6	+69	18	13*d*	R Delphini	20	10.1	+ 8	47	13*f*
R Comae	11	59.1	+19	20	*f*	U Cygni	20	16.5	+47	35	9*i*
T Virginis	12	9.5	− 5	29	11*i*	V "	20	38.1	+47	47	12*i*
R Corvi	12	14.4	−18	42	8*i*	T Aquarii	20	44.7	− 5	31	8*i*
Y Virginis	12	28.7	− 3	52	10*i*	R Vulpec.	20	59.9	+23	26	10*d*
T Urs. Maj.	12	31.8	+60	2	11*d*	T Cephei	21	8.2	+68	5	7*i*
R Virginis	12	33.4	+ 7	32	9*i*	S "	21	36.5	+78	10	7*i*
S Urs. Maj.	12	39.6	+61	38	11*d*	S Lacertae	22	24.6	+39	48	*u*
U Virginis	12	46.0	+ 6	6	9*d*	R "	22	38.8	+41	51	13*f*
V "	13	22.6	− 2	39	9*i*	S Aquarii	22	51.8	−20	53	13*f*
R Hydrae	13	24.2	−22	46	8*i*	R Pegasi	23	1.6	+10	0	12*d*
S Virginis	13	27.8	− 6	41	9*d*	S "	23	15.5	+ 8	22	9*i*
R Can. Ven.	13	44.6	+40	2	*f*	R Aquarii	23	38.6	−15	50	8*i*
S Bootis	14	19.5	+54	16	8*d*	R Cassiop.	23	53.3	+50	50	7*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, McCormick, Eadie, Vassar College and Harvard Observatories, Jan. 10, 1904.

Change in the Time Used in the Variable Star Tables.—At the urgent request of some of the variable star observers we have decided to give the variable star data in Greenwich Mean Time (Astronomical) instead of Greenwich Civil Time as we have done for the past three years. Heretofore we have taken much of the data from the "Companion to The Observatory" and the "Annuaire du Bureau des Longitudes" which use civil time, and to guard against errors we preferred not to convert the time into astronomical time. Now our plan will be to compute the tables entirely from the latest available elements. This month the minima of the Algol Type variables have been independently computed from the Revised Elements just published by Chandler, so far as they applied, and from the best elements we could find for the stars not in Chandler's list. We hope variable star observers will inform us promptly of any errors and of improved elements which may be used.

Revision of the Elements of Chandler's Third Catalogue of Variable Stars.—In the *Astronomical Journal* No. 553 Mr. S. C. Chandler gives the results of a revision of the elements of the stars contained in his *Third Catalogue of Variable Stars* (*A. J.* 379), utilizing all the suitable material for that purpose that has been published since that Catalogue was issued.

New Variable Star 62.1903 Andromedæ.—This is the star BD $+ 43°.462$, R. A. $2^h\ 8^m\ 37^s.2 + 43°\ 37'.5$ (1855.0) and is a companion to the variable W Andromedae, which it follows by $11^s.6$ on the same parallel. Father J. G. Hagen, S. J., of the Georgetown College Observatory, gives, in *A. N.* 3917, 10 observations of this star in 1900-1903, which tend to show that its light varies from 9.9 to 8.8, probably in a long period. The color of the star is reddish yellow.

New Variable Star 63.1903 Lyræ.—Rev. T. D. Anderson announces this in *A. N.* 3920. It is not found in the BD. but its approximate position for 1855 is

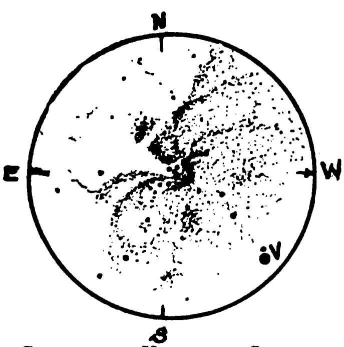
R. A. $19^h\ 08^m.8$; Decl. $+ 46°\ 43'$.

"On Nov. 2 1903 it was of the 9.2 magnitude, but on Dec. 6 it was only $10^m.1$ and on Dec. 14 $10^m.3$. These values have been arrived at on the assumption that BD. $+ 46°.2649$, 2650 and $47°.2789$ are $10^m.1$, $9^m.5$ and $8^m.4$ respectively, and that a star not inserted in the BD. which lies about $2'$ to the s. f. of $+ 46°.2649$ is $10^m.5$. It may be mentioned that $+ 46°.2649$ precedes by about 15^s the place in which it is laid down on the BD. chart."

The Variable Star ε Aurigæ.—In *A. N.* 3918-20 Mr. H. Ludendorff gives the results of an extensive study of the light changes of this star which has been known for many years as an irregular variable. His conclusion is that ε Aurigæ is a variable of the Algol type but of the very long period of 9905 days or 27.12 years. As a rule its magnitude is 3.35; in falling to minimum it occupies 207 days and declines about 0.73 of a magnitude. It remains constant at minimum for about 313 days and then in 207 days rises to its former brightness. After that it remains at its ordinary magnitude for 25.13 years. Mr. Ludendorff has made use of the observations of fifteen reliable observers covering pretty

completely the period from 1842 to 1903. He admits that that duration of the decline and increase, as well as of the period of constancy at minimum, are somewhat uncertain. The latter may be greater than 313 days and the former may be less than 207 days. The spectrum of the star shows that it consists of two bright bodies and it may be that the real period is 54¼ years instead of 27.12. The next minimum should occur in the years 1928-30.

Suspected Variable in the Orion Nebula.—Mr. Chas. P. Foster of Waterloo, Ia., calls attention to a star in the Orion nebula, marked V in the accompanying sketch. Ordinarily it seems considerably brighter than the companion star, just above it in the sketch, but upon the nights of March 7, 1896, Jan. 28, and Jan. 29, 1897, it seemed fainter than usual. On the last mentioned night the two stars were noted as equal in brightness.



SUSPECTED VARIABLE STAR IN THE ORION NEBULA.

The star is BD — 5°,1301 mag. 9.1 and its position for 1855 is

R. A. $5^h\ 27^m\ 26^s.9$; Decl. $-5°\ 49'.0$

It is not a known variable, although there is a list of over 20 variables in the Nebula of Orion. On seven or eight photographs of the Nebula taken at Goodsell Observatory the star shows no variation, being always brighter than the neighboring star BD — 5°,1303.

U Orionis.—The enclosed charts represent the light curve of the variable star U Orionis ($\alpha = 5^h\ 49^m\ 54^s$, $\delta = +20°\ 10'\ 0''$) based upon observations taken here from December 31st, 1901 to May 17th, 1902 and from February 23d, 1903 to May 14th, 1903, by the Argelander method. This is the variable that was discovered by Gore in Ireland on December 13th, 1885, and at first was thought to be a Nova. Its period seems to vary from about 360 to 377 days. The maxima vary from 5.9 magnitude to 6.3 magnitude, but the minima are all near 12.5 magnitude. According to my observations the 1902 maximum occurred about May 5th, the star rising to 5.9 magnitude whereas the 1903 maximum occurred about April 27th, the star rising to only 6.28 magnitude. This is one of the long period variables that resembles *o* Ceti in many ways. It has a spectrum of Secchi's third type, and is very red in color especially near its maximum brightness.

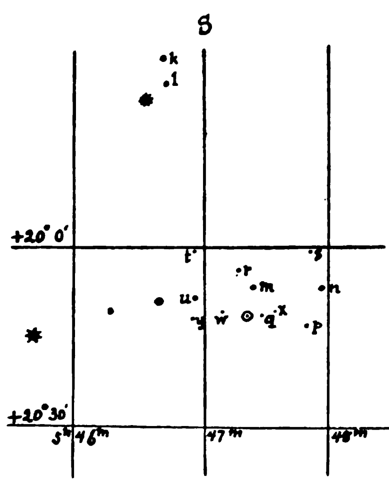
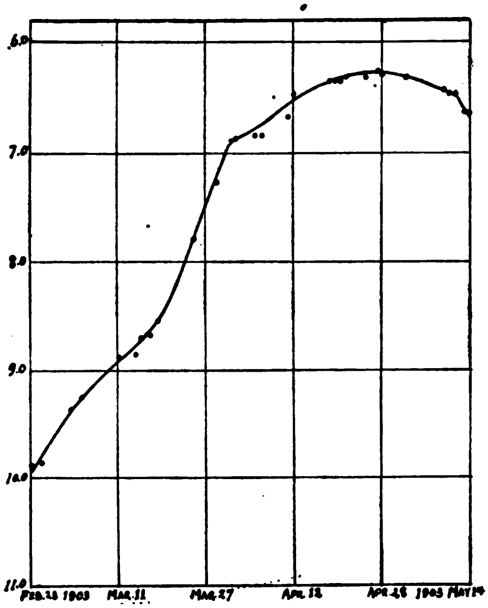
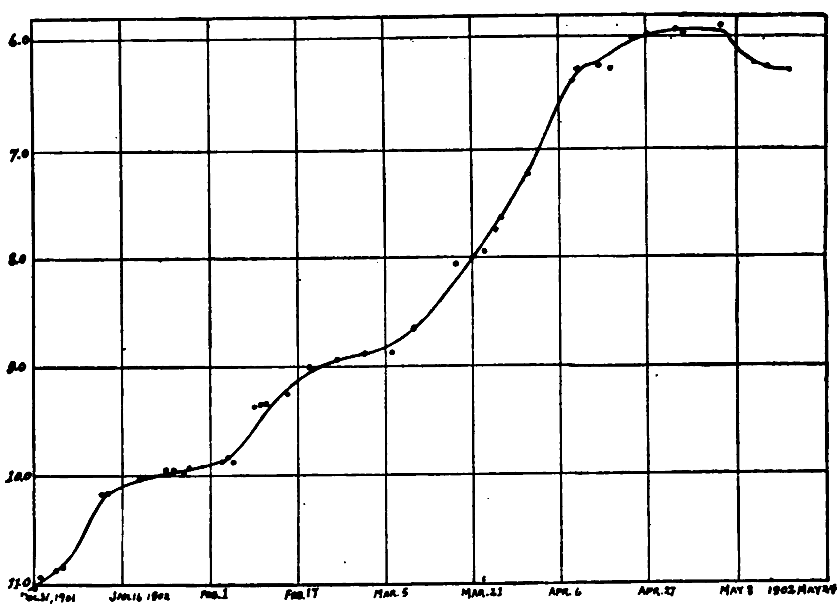


CHART OF COMPARISON STARS FOR U ORIONIS.



Light Curve of U Orionis in 1903.



Light Curve of U Orionis in 1902.

Observations of U Orionis.

75th Meridian Time.					J. Day.	Comparison.	
y	m	d	h	m			
1901	12	31	8	50	2415750	Var = s	
1902	1	1	10	5	5751	r3VV½s	Clouds.
	"	4	9	50	5754	r2½VV1s	
	"	5	9	10	5755	r2VV1s	
	"	12	8	25	5762	Var = q	
	"	13	8	20	5763	Var = q	
	"	19	7	40	5769	p2½VV½q	
	"	24	8	50	5774	p2VV1½q	
	"	25	8	10	5775	p2VV1½q	
	"	27	8	35	5777	p2VV1q	
	"	28	8	10	5778	p1½VV1½q	
	2	3	8	55	5784	p1VV2q	
	"	4	7	35	5785	p½VV2q	
	"	5	10	15	5786	p1VV2q	
	"	9	7	45	5790	n1½VV½p	
	"	10	7	20	5791	n1½VV1p	
	"	11	8	0	5792	n1½VV1p	
	"	15	9	0	5796	n½VV2p	
	"	19	6	45	5800	Var = n	
	"	24	8	10	5805	m2VV2½n	
	3	1	8	15	5810	m2VV3n	
	"	6	8	30	5815	Var = m	
	"	10	8	20	5819	l3VV1½m	
	"	18	7	25	5827	k½VV1½l	
	"	23	8	20	5832	Var = k	
	"	25	7	55	5834	h1½VV2k	
	"	26	8	10	5835	Var = h	
	"	31	7	30	5840	g½VV2½h	
	4	9	7	55	5849	e1½VV2f	
	"	13	7	40	5853	e1½VV2½f	
	"	15	7	45	5855	e1½VV2f	
	"	19	7	35	5859	Var = e	
	"	22	7	45	5862	d2VV½e	
	"	27	8	5	5867	d1½VV1e	
	"	28	8	0	5868	d2VV½e	
	5	5	8	20	5875	d1½VV1½e	
	"	11	7	45	5881	e1VV2½f	Twilight.
	"	13	7	40	5883	e1VV2f	"
	"	17	8	10	5887	e1VV1½f	
1903	2	23	9	25	2416169	p1VV1½q	
	"	25	7	55	6171	p1VV2q	
	3	1	7	55	6175	p1VV2q	
	"	2	7	45	6176	n1½VV½p	
	"	4	7	45	6178	n½VV2p	
	"	11	9	25	6185	m1½VV2½n	
	"	14	7	50	6188	Var = m	
	"	15	8	50	6189	l3VV½m	
	"	17	7	55	6191	e2½VV1½m	
	"	18	7	25	6192	l2VV2m	
	"	25	7	55	6199	h1½VV1k	
	"	29	7	15	6203	g1½VV2½h	
	"	31	7	35	6205	f2½VV1½g	
	4	1	7	35	6206	f3VV1½g	
	"	5	7	45	6210	f2VV2½g	
	"	6	7	10	6211	f2VV2½g	
	"	11	7	30	6216	f1VV4g	
	"	12	7	20	6217	e3½VV½f	
	"	18	7	20	6223	e2½VV2f	
	"	19	7	35	6234	e2½VV1½f	
	"	20	7	35	6225	e2½VV1½f	

OBSERVATIONS OF U ORIONIS.—Continued.

75th Meridian Time.					J. Day.	Comparison.	
y	m	d	h	m			
1903	4	21	7	5	2416226	e2VV2f	Twilight.
	"	25	7	25	6230	e2VV2f	"
	"	27	7	25	6232	e1½VV2½f	"
	"	28	7	35	6233	e2VV2½f	"
	5	2	7	20	6237	e2VV2f	
	"	9	7	40	6244	e3VV1f	"
	"	10	7	35	6245	e3½VV1f	"
	"	11	7	45	6246	e3½VV1f	"
	"	12	7	45	6247	e4VV1f	Poor obs.
	"	13	8	10	6248	Var = f	"

F. E. SEAGRAVE.

PROVIDENCE, Dec. 16th, 1903.

GENERAL NOTES.

Meeting of the Astronomical and Astrophysical Society of America, at St. Louis, Dec. 29-30, 1903.—The Society met in affiliation with Section A (Astronomy and Mathematics) of the American Association for the Advancement of Science in one of the rooms of the central high school building at St. Louis. The attendance was smaller than usual and the program was short. The officers elected for the ensuing year were

President:	Simon Newcomb
Vice Presidents:	George E. Hale W. W. Campbell
Treasurer:	C. L. Doolittle
Councillors:	E. C. Pickering R. S. Woodward

The permanent Secretary is Geo. C. Comstock, Director of Washburn Observatory, Madison, Wis.

The following papers were presented, nearly all being read in full. Several of the writers were not present, but their papers were read by others.

1. On the Rotation Period of Saturn. G. W. Hough, Dearborn Observatory.
2. The Prediction of Occultations of Stars by the Moon. G. W. Hough.
3. The D. O. Mills Expedition. W. W. Campbell, Lick Observatory.
4. The Sun's Motion Relative to a Group of Faint Stars. G. C. Comstock, Washburn Observatory.
5. The Absorption of Solar Radiation by the Sun's Atmosphere. F. W. Very, Washington, D. C.
6. Facilities for Astronomical Photography in Southern California. E. L. Larkin, Lowe Observatory.
7. Borrelly's Comet *c* 1903. Sebastian Albrecht, Lick Observatory.
8. The Pivots of the 9-inch Transit Circle of the U. S. Naval Observatory. W. S. Eichelberger, U. S. Naval Observatory.
9. The Supporting and Counterweighting of the Principal Axes of Large Telescopes. C. D. Perrine, Lick Observatory.
10. A Short Sketch of the Progress of Astronomy in the United States. M. S. Brennan, St. Louis, Mo.

11. The Eros Parallax Photographs at Goodsell Observatory. H. C. Wilson, Goodsell Observatory.

12. A New Type of Transit-Room Shutter. D. P. Todd, Amherst College Observatory.

The roster of members present was: Simon Newcomb, Washington, D. C,, R. S. Woodward, Columbia College, New York, Ormond Stone, Leander McCormick Observatory, Geo. C. Comstock, Washburn Observatory, W. S. Eichelberger, U. S. Naval Observatory, Chas. S. Howe, Case School of Applied Science, Cleveland, O., Joel Stebbins, Urbana, Ill., L. G. Weld, University of Iowa, O. H. Tittmann, U. S. Coast Survey, Washington, D. C., H. C. Wilson, Goodsell Observatory, Martin S. Brennan, St. Louis, A. Lawrence Rotch, Boston, Mass., G. W. Hough, Dearborn Observatory, Edgar L. Larkin, Lowe Observatory.

A Fine Conjunction.—On the 20th of December, 1903, the lovers of the sky had the opportunity to observe a fine spectacle. Reddish Mars and pale Saturn met as good friends and almost shook hands. In the city of Mexico the phenomenon was visible in clear atmospheric conditions. About half past six in the evening, with the sky of a violet color, something like the color of the

vapor of iodine, the two beautiful planets, Mars and Saturn, shone finely in the southwest. Even persons who have no knowledge of the beauties of astronomy noted that friendly meeting. It was a fine view, indeed. As the sky became darker, the view grew finer. Unfortunately, soon after, the two planets were lost in the mist of the horizon. PROF. LUIS G. LEON.

MEXICO CITY, December 21st, 1903.

Dr. Swift's Perpetual Calendar.—Dr. Lewis Swift, late Director of the Mt. Lowe Observatory, California, and now of Marathon, N. Y., has recently sent me a model of a perpetual calendar, invented by himself. It is adjustable, one side to any date in the 18th or 19th century, the other side to any date in the 20th century. Even the leap years are fully provided for. At the center a revolving disc has for its circumference the days of the week, four times repeated; in columns with these, leading toward the center of the disc, appear the various years of the century, properly arranged, with a blank immediately preceding each leap year. Above, in columns to match these are properly distributed the names of the months; below, in similar columns are arranged the numerals for the 30 days of the month. To ascertain the day of the week on which one was born, place the year of his birth in the column with the month of his birth, and at the bottom the day of the month will be found in the column with the day of the week. Thus I ascertain that one born July 1st, 1850, was born on Monday. Dr. Swift, himself, a leap year baby, born on Feb. 29, 1820, was born on Wednesday. Looking ahead, he will celebrate his 20th birthday, but the completion of his 84th year, on Tuesday, Feb. 29, 1904. Thus the calendar, so ingeniously contrived, works in both directions. Whether or not it is Dr. Swift's intention to have these prepared for general use, I have not learned. FREDERICK CAMPBELL.

BROOKLYN, N. Y.

Insertion.—Page 78, eighth line from bottom insert: "The photograph was taken September 2, 1901, 11.3 days after sunrise, colongitude 149°. While therefore it was taken about three days later in the lunation than the drawing, still it does not show any very marked changes to have occurred in the mean time, excepting possibly in the relative intensity of some of the canals.

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N

W

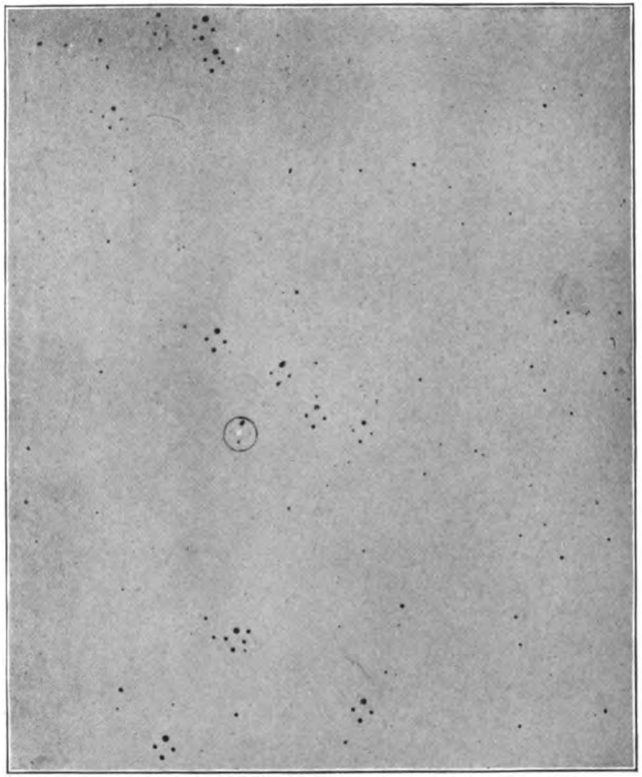

Fig. 5—Nov. 24, 1900, 6:08–6:26 C. S. T.
Star used for guiding.

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E

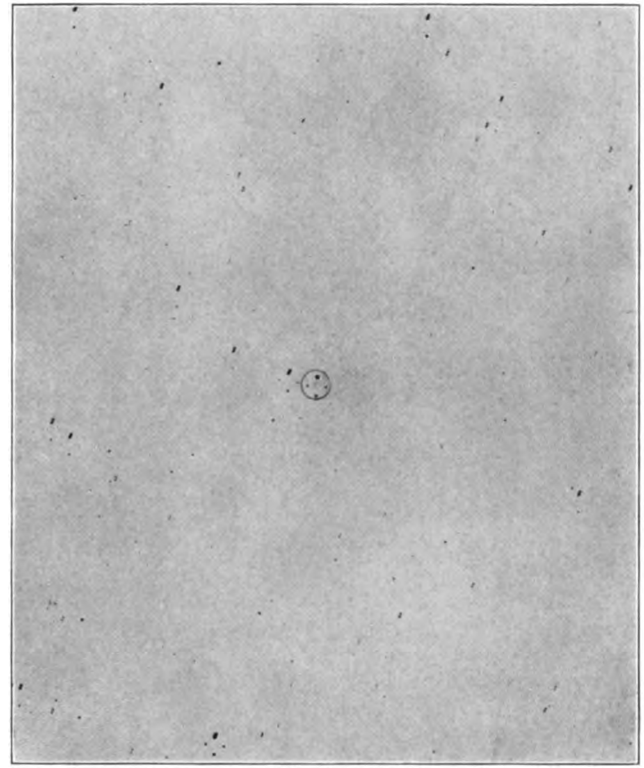


Fig 6—Nov. 30, 1900, 6:00–6:18 C. S. T.
Eros used for guiding.

Central Portions of Two Negatives of the Region about Eros, taken at Goodsell Observatory.

The reproductions have been enlarged to three times the scale of the original negatives. A circle has been drawn around the images of Eros.

Popular Astronomy.

Vol. XII No. 3. MARCH, 1904. Whole No. 113.

MEASURING THE DISTANCE OF THE SUN BY MEANS OF THE PLANET EROS.

H. C. WILSON.

The writer having recently finished the reduction of measures of 67 photographs of the planet Eros, which were taken during the Fall and Winter of 1900-01 for the purpose of determining the solar parallax, was interested in comparing the results with the similar photographic results published by the Observatories of Paris and Bordeaux, and in getting out from the three sets of measures a preliminary value of the parallax. The three sets agree so well and exhibit so well the accuracy of the photographic method that Professor Payne has asked me to prepare an article describing as plainly as possible the process of attacking the problem.

We wish here to acknowledge our indebtedness to Professor Leavenworth and the authorities of the University of Minnesota for the loan during the summer of 1902 of the fine Repsold Measuring machine belonging to the University Observatory, to the Trustees of the B. A. Gould Astronomical Fund for two grants of money, amounting in all to $550, and to Dr. DeLisle Stewart now of the Cincinnati Observatory, and Professor Anne S. Young of Mt. Holyoke Observatory, for their valuable assistance in the work of measuring and reducing the photographs.

A short historical note is necessary first to the clear understanding of the problem.

On the 13th of August 1898, Mr. Witt of the Urania Observatory in Berlin, discovered on one of his stellar photographs a small planet to which he afterwards gave the name of Eros. It had been photographed by Mr. Charlois, at the Observatory of Nice, a few hours earlier on the same night but was not discovered by him until later. Now the discovery of a small planet ordinarily attracts little attention, for a dozen or more of them are discovered every year, but this one excited interest at once because of its extraordinarily rapid apparent motion. When its orbit was calculated it was found to be moving in an orbit which at times approaches nearer to the path of the Earth than does

the track of any of the other known planet, great or small, its average distance from the Sun being less than that of Mars. At its nearest possible approach it may come within 13,000,000 miles of the Earth. It is a tiny planet, probably not more than 20 miles in diameter, appearing in the most powerful telescope as a very small bright point of light with no measurable disc. On account of these two things, the nearness of the planet's approach to the Earth and the smallness of its image as seen in the telescope or impressed upon the photographic plate, thus permitting its position in space to be measured with extreme accuracy, Eros becomes an important body in the solar system. It was at once pointed out that Eros afforded a far better means of obtaining the parallax of the Sun, and so the distance of the Earth from the Sun, than any that had been hitherto employed. Some of the asteroids had already been used in determining the Sun's parallax and had yielded very satisfactory results, but those used did not approach anywhere near so close to the Earth as does Eros, so that from the latter much more accurate results may be expected.

Unfortunately Eros and the Earth do not often pass the points of nearest approach of their orbits at the same time. The relation of the two orbits is shown in the diagram Fig. 1. Eros makes a complete circuit around the Sun in 1.76 years, while the Earth revolves in one year. If the two planets were to start together near the point P, while Eros would make the circuit of its orbit once, the Earth would go around its path once and three-quarters of the way again, and in 2.31 years the latter would overtake the former, almost a third of the way around its second circuit. After 2.31 years more the two planets would again be in conjunction, etc. After seven years the two would be near the point P together, but not in line with the Sun so as to give the shortest distance. The actual conjunction of the planets (opposition of Eros) would occur about 30° around to the right from P. A quite close conjunction occurs after 30 years and a still closer one after 37 years have elapsed. If the elements of the orbit of Eros have not been changed too much by the attraction of the other planets, there was a very close conjunction in 1880. Another will occur therefore in 1917 and a less favorable one in 1910.

At the international conference of astronomers at Paris in 1900, it was decided not to wait for the most favorable oppositions of Eros in 1910, 1917 and 1924, but, since at the opposition in 1900 the planet would come nearer to the Earth than had any

other planet, to enter at once upon a coöperative campaign for determining the parallax of Eros, using both the micrometric and photographic methods. Circulars were sent out from Paris to all the Observatories, asking them to take part in the work. Forty-seven Observatories responded, agreeing to take some part in the work. Of these ten were in the United States, one in Mexico, and two in South America; thirty-two were in Europe and two in Africa. The path of the planet was calculated for the

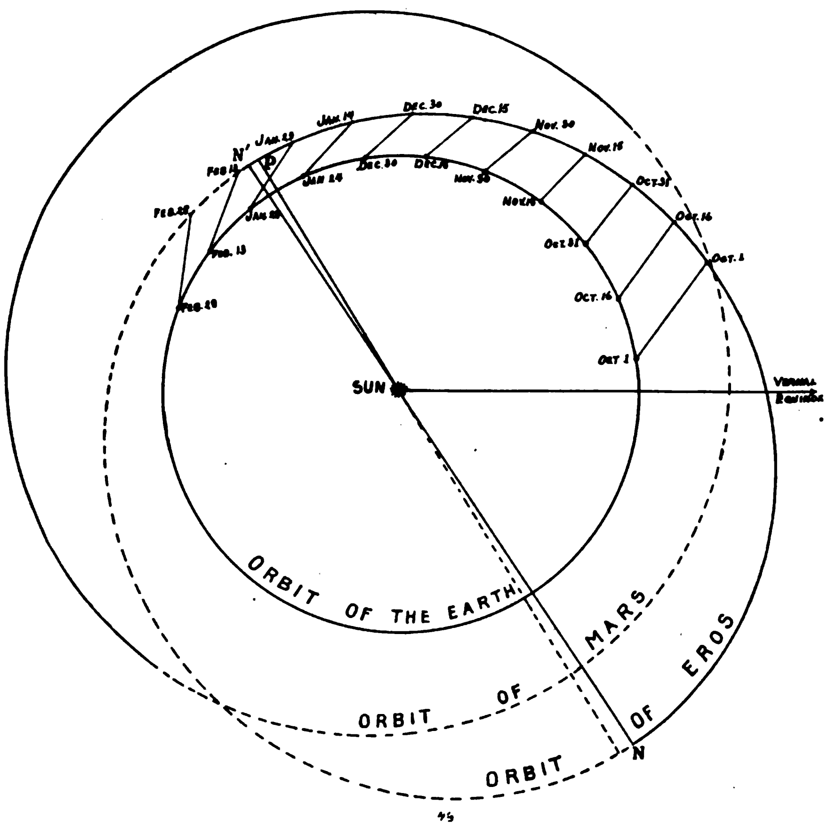


FIG. 1. THE RELATIVE POSITIONS OF EROS AND EARTH FROM OCT. 1, 1900 TO FEB. 28, 1901.

period when it was to be near the Earth and a list of over 700 stars lying near its path was selected for reference stars for the measurement of the photographs. The places of these stars were determined very accurately with the meridian circles at thirteen observatories, during the period in which the planet was being observed. The observatories joining in this part of the work, whose results have been published, were those of Abbadia, Green-

wich, Koenigsberg, Lisbon, Lick, Marseilles, Nice, Paris, Rome, Toulouse, San Fernando, Strassburg and Washington.

The following list of observatories took part in the micrometric measures or photographs of the planet, M signifying micrometer and P photographs, the figures following the letters denoting the number of nights on which the planet was observed:

Algiers, P 84	Lyons, M 36
Arcetri, Florence, M 29	Madison, Washburn, M 60
Bamberg, Heliometer 48	Marseilles, M 74
Besancon, M 32	Minneapolis, University, P 59
Bordeaux, M 12, P 34	Mt. Hamilton, Lick M 29, P 68
Cambridge, Eng., P 39	Nice, M 69; several instruments
Catania, P	Northfield, P 56, M 21
Cape of Good Hope, P	Oxford, P 52
Charlottesville, McCormick, M 27	Padua, M 41
Christiana, M 50	Paris, M 58, P 68
Cordoba, M 17, P 3	Poulkova, M 50, P 27
Denver, M	San Fernando, P 51
Dublin, P 17	Strassburg, M 33
Dusseldorf, M, 11	Tachkent, P 23
Edinburgh, M 22	Tacubaya, M 61 P
Flagstaff, M 19	Teramo, M 100
Greenwich, P 98	Toulouse, M 47, P 36
Helsingfors, P 48	Uccle, Belgium, M 2
Kasan, M 15	Upsala, P 30
Kœnigsberg, M 88	Washington, M 61
Königstuhl, Heidelberg, P 6	Williams Bay, Yerkes, M 67

As may be inferred from the above table, a great mass of material was at once accumulated for the solution of the problem, but it all had to be reduced and published before it could be made available for its purpose, and a very great amount of work has been done upon it during the past three years. There is very much yet to be done, especially in the measurement and reduction of the photographic plates, which is very tedious business, so that it will be a long time yet before the final parallax can be determined. All the more interest will therefore attach to the preliminary values, which may indicate somewhere near what the final result may be.

The Plan of the Observations.

In speaking of the details of the work I shall have to refer chiefly to the plan carried out at Northfield, since no specific instructions were given out and each observer had to devise his own methods of carrying out the general plan. If the reader will refer to the diagram Fig. 1, he will see that Eros was roughly opposite the Sun, as seen from the Earth, from October 1900 to February 1901, so that it might be observed during the greater part of the night. In order to imagine how the planet moved through the sky one must think of the orbit of Eros as inclined to the plane of the paper, being rotated on the line of Nodes NN′

through an angle of ten degrees, the smooth part of the curve standing in front of the paper and the dotted portions behind it. The line Oct. 1—Oct. 1 thus stands up at an angle of about 45°, instead of lying flat on the paper. Now imagine the eye to move along the Earth's path, looking out at the planet as it moves across the sky, and the reader can possibly see that it will describe a great loop in the heavens. In Fig. 2 a portion of the apparent path of Eros among the stars is shown, extending from Sept, 20, 1900 to Jan. 6, 1901. This chart was prepared by the writer in 1900, in order to easily identify Eros at the time when a photograph or a micrometer measure was to be taken. The chart shows only the stars down to the magnitude 9.5, while Eros much of the time was considerably fainter and there were thousands of otherfaint stars along its path, but it was possible by the aid of the chart to locate its place closely enough for a photograph, or so that a few minutes micrometer measures would decide which of the faint objects near its place was really the planet.

The general plan of work was that each of those observers who were provided with photographic telescopes should take photographs of the region about the planet all along its path from October to February, each photograph covering a field of approximately 2° diameter, and that, those working with micrometers should measure the distance between the planet and the nearest stars to it on each night, trusting to the photographs to give them the exact positions of these stars.

Two plans were adopted for arranging the times of the observations. One was to make them simultaneous at stations far apart on the Earth, at a favorable moment for both stations; the other was to make them at widely different hours at the same station, that is in the morning and evening. The theories of the two plans are shown in the diagrams Fig. 3 and Fig. 4. In Fig. 3, since the difference in longitude between Paris and Northfield is a little over six hours, the best time to make simultaneous observations would be when Eros was over the meridian midway between the two cities, that is, about three hours before Eros passed the meridian at Northfield and three hours after it had passed that of Paris. Eros would then be near the star *b* as seen from Northfield, but near the star *c* as seen from Paris, while its true direction from the center of the Earth would be toward the star *a*. This displacement is called the parallax of Eros and it depends clearly upon the distance of the planet from the Earth and the distance between the observing stations. The

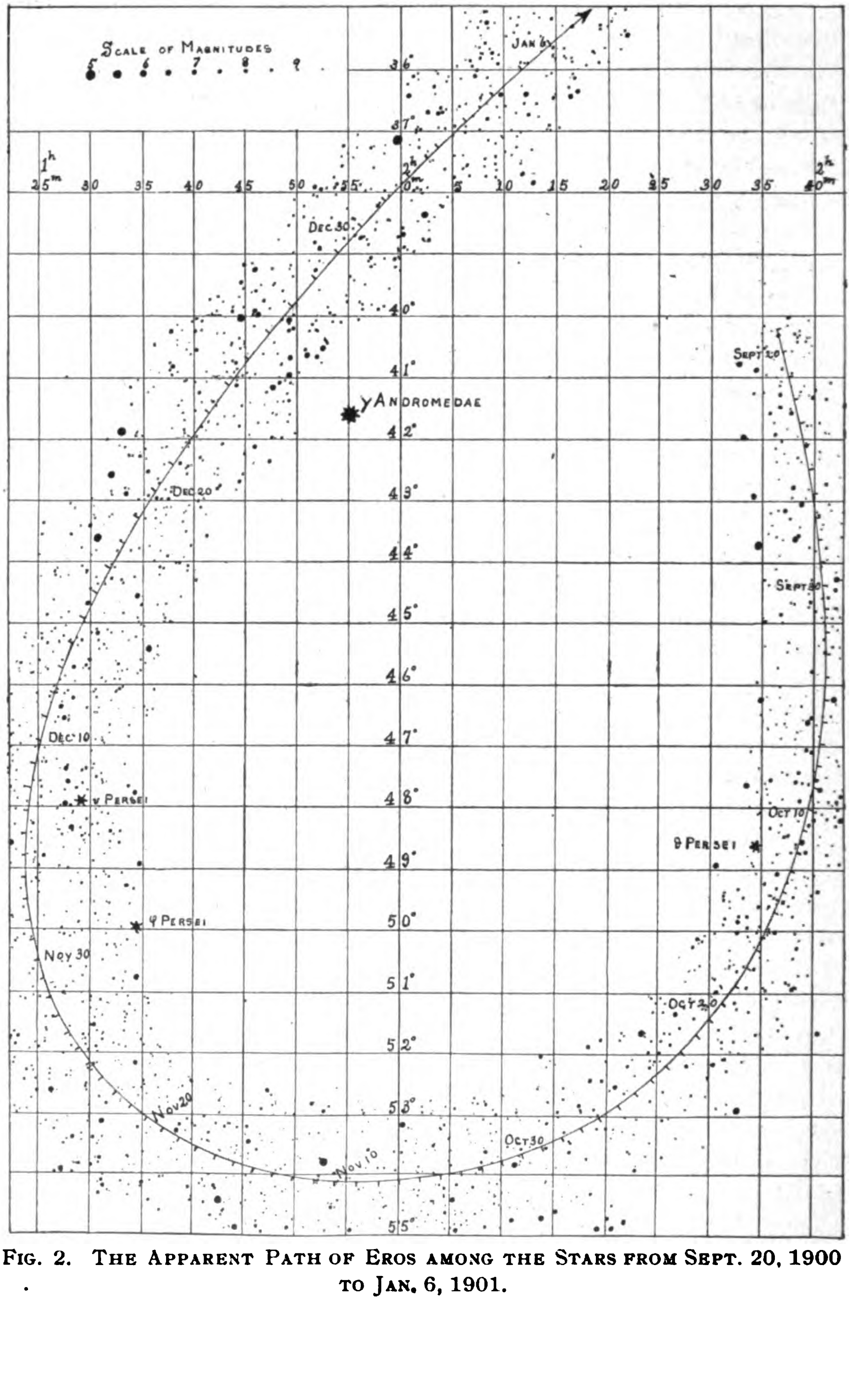


FIG. 2. THE APPARENT PATH OF EROS AMONG THE STARS FROM SEPT. 20, 1900 TO JAN. 6, 1901.

greater the latter and the less the former, the greater the parallax. Theoretically this first plan avoids the errors which might enter into the calculation of the position of Eros from the elements of its motion which are not exactly known. Practically, however, very few of the observations in Europe and America

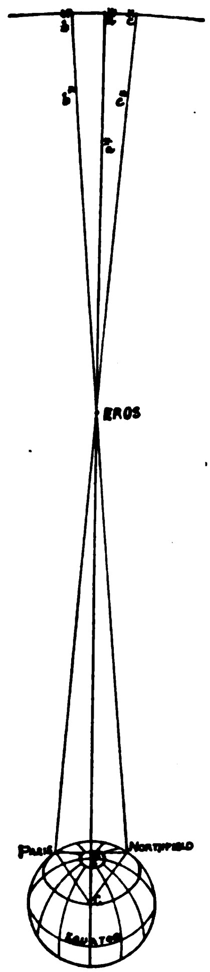


FIG. 3.

are found to have been simultaneous, so that equally good if not better results are to be expected from the second plan.

As seen from the same Observatory when the planet is from 4 to 6 hours east of the meridian and when it is as far to the west (evening and morning, Fig. 4) the displacement with reference to neighboring stars is greater than in the former case, for the observing stations are farther apart. An extremely accurate ephemeris of Eros has been calculated by Professor Millosevich, Director of the observatory at Rome. He has used eight-place logarithm tables so that the right ascensions are computed to the thousandth of a second of time and the declinations to the hundreths of a second of arc. I have been surprised at the extreme accuracy of this ephemeris and believe that the effects of its errors may be easily eliminated from the parallax.

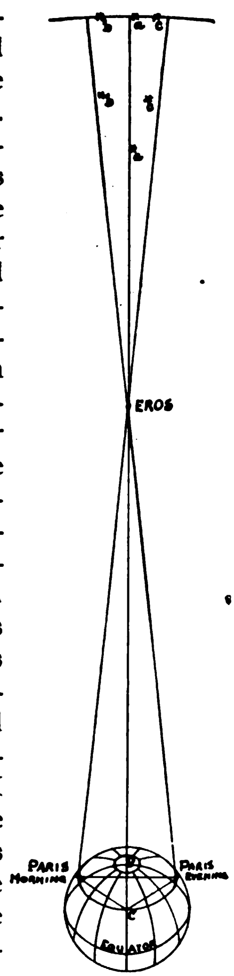


FIG. 4.

In both Figs. 3 and 4, of course, the parallax is greatly exaggerated. If the figures were drawn to scale, with the Earth ⅝ of an inch in diameter Eros at its nearest would have to be represented as 80 feet distant and the stars would be two or more million times as far. Their distance is such that their displacement as seen from the two stations on the Earth is wholly negligible. The angle at Eros between the two lines extending to points

upon opposite sides of the Earth is at most a little over two minutes of arc.

The Photographs.

At Northfield the photographs were taken with the 8½-inch Clark refractor of 107 inches focal length. This telescope has three objective lenses, which give sharp small star images over the greater part of a field two degrees in diameter. It is provided with a 5-inch guiding telescope, of the same focal length, fastened rigidly to it at the objective and eye ends and in the middle. The plates used were ordinary commercial plates, of the Cramer Crown brand, 4x5 inches in size. No reseaux was impressed upon the plates as was done in the European Observatories. For making separate exposures on the same plate a reticle of spider threads illuminated by an electric lamp was placed in the eyepiecc of the guiding telescope, forming a small rectangle which was adjusted to the center of the field of the photograph. Five exposures were usually made, one of five minutes duration with the guiding star at the north corner of the rectangle, one of one minute at the east corner, the third of two minutes at the south corner, the fourth of one minute at the west corner and the fifth of five minutes duration again at the north corner, the images of each star at this corner being superposed. In the mean time the planet would have moved so that its two five-minute images would be entirely separate, making the north image double. It was thus very easy to identify the planet among the neighboring stars. In Fig. 5 (Plate VII) is given a print from the central portion of one of the places. It has been enlarged to three times the scale of the original plate in order to make the images large enough to reproduce by half-tone engraving, but still many of the images are too small to show. The guiding star was the right lower one of the three brightest ones near the center. The planet is a centimeter to the left and a little below the guiding star. Above and to the right of it. the middle one of the three bright stars is an unequal double. Fig. 6 gives the central portion of a plate in which Eros itself was used as the guide. Its two north images in this case are superposed, while because of its motion every star has a double image at the north corner of the square.

Measuring the Photographs.

During the summer of 1902 Dr. DeLisle Stewart and the writer, with minor assistants as recorders, were able to measure all of our Eros plates, with the exception of a few which were rejected

because of imperfect star images. Each plate was placed in the Repsold measuring machine in four positions, differing by angles of 90°. A complete set of measures of differences in right ascension, or rather in the x-co-ordinate corresponding to right ascension, between the planet and eight or ten reference stars, was taken with the position circle of the machine set at the reading corresponding to 0°. The plate was then revolved exactly 180° and a second set of measures of the x-co-ordinates made. It was turned then through just 90° and a set of measures of the co-ordinates, corresponding to difference of declination, taken. Once more the plate was revolved through 180° and a second set of measures of the y co-ordinates was taken. Each single measure consisted in two pointings of the micrometer wires of the machine upon each of the four or five images of the planet or of a star and four pointings upon the one of two nearest scale divisions. All the precautions we could think of were taken to eliminate systematic errors in the measures, such as forward and backward movement of the screw, pointing on the scale both before and after the pointings on a star, etc. Duplicate pointings were made on the central or guide star and on Eros at the beginning and end of each of the four sets of measures of each plate. These duplicate measures usually agreed within 0″.10. The following is a portion of one of the original records:

Measures of Plate 10, July 2, 1902.

Position Circle	0° 45′ 2″			180° 44′ 59″		180° 45′ 6″			0° 44′ 59″	
	Scale			Micrometer.		Scale			Micrometer.	
Star.	Estimates.			rev.	rev.	Estimates.			rev.	rev.
46°.641	$64^{d}.3$	$264^{d}.1$	Scale	9.516	9.517	$64^{d}.2$	$266^{d}.7$	Scale	9.294	9.294
			Images N	10.981	10.984			N	11.098	11.101
Temp. 73°.3			E	10.243	10.242	Temp. 73°.9		E	11.834	11.838
			S	11.174	11.165			S	10.906	10.901
			W	11.864	11.872			W	10.212	10.206
			N	10.985	10.984			N	11.103	11.100
			Scale	11.517	11.516			Scale	11.296	11.296
Eros	57.5	260.1	Scale	10.002	10.002	70.9	270.7	Scale	10.813	10.813
			N	10.963	10.971			N	11.118	11.123
			E	10.138	10.144			E	11.933	11.944
			S	11.152	11.156			S	10.920	10.934
			W	11.902	11.894			W	10.184	10.191
			N	10.920	10.924			N	11.161	11.164
			Scale	12.002	12.005			Scale	12.817	12.817
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......

The entire record of the original measures of this plate covers nineteen times the above space, and the time occupied was about seven hours.

As 10 revolutions of the micrometer screw of the measuring

machine equal one millimeter, an inspection of these measures shows that the error of pointing upon the scale divisions was only 1 or 2 ten thousandths of a millimeter or about one-hundredth of a second of arc, the scale of our plates being 1 millimeter = 75.9″. The pointings upon the star images were subject to about ten times as great errors on the average, that is about ± 0″.10. On the plates on which the definition was poor, and where the star images were large the errors were found to be considerably larger, amounting to ± 0″.30. Very few single pointings show discrepancies as large as 1″.

Reduction of Measures.

The reductions occupied much more time than the measures themselves. First the separate pointings on each image were averaged, then corrections were applied for the errors of the scale divisions and the error of runs of the micrometer. Then the micrometer readings were converted into scale reading in millimeters and the differences were taken which gave the rectangular co-ordinates x and y of each image from the corresponding image of the guide star at the center of the plate. Then the means were taken of the measures made in the two opposite positions of the plate for each co-ordinate, and finally the averages of the co-ordinates as obtained from the five different images were taken. It was found after a number of preliminary reductions that the results obtained from the averages of the five images was the same as if the co-ordinates of the five images were reduced separately and afterwards averaged. Next the averaged co-ordinates were converted into seconds of arc by multiplying x by 75.9″ sec δ_0, and y by 75.9″, δ_0 being the declination of the center of the plate and 75.9″ the approximate value of one division of the scale or 1mm. This was done both by the use of Crelles multiplication table and by the use of six-place logarithms, for a complete check upon that step. The previous steps were checked quite satisfactorily by the comparison of the results from the different images.

The next step was to calculate the same rectangular co-ordinates, x sec δ_0 and y, from the positions of the stars as given by the meridian circle observations of the thirteen Observatories, as published in circulars 8 and 9 of the International Conference. This was also done in duplicate by two computers by two entirely different methods. One computer used the following modification of Turner's formulæ, which adapts them to the use of seven-place logarithms for small angles:

$$\cot Q = \cot \delta \cos (\alpha - \alpha_0)$$

$$Y = \tan (Q - \delta_0) = Q - \delta_0 + \frac{1}{3} (Q - \delta_0)^3 \sin^2 1'' + \frac{2}{15} (Q - \delta_0)^5 \sin^4 1'' + \text{etc.}$$

$$= Q - \delta_0 + t$$

$$X \sec \delta_0 = (\alpha - \alpha_0 + t) \cos Q \sec \delta_0 \sec (Q - \delta_0)$$

in which α and δ are the right ascension and declination of a star for 1900.0, α_0 and δ_0 are the similar co-ordinatesof the center of the plate (the guiding star in this case), and t is the reduction of the arc to the tangent for the angle to which it is added and is taken from a small table which is easily prepared.

The second computer used five-place logarithms, employing Jacoby's formulæ

$$X \sec \delta_0 - \Delta\alpha = - \Delta\alpha \,.\, \Delta\delta \tan \delta_0 \sin 1'' + \Delta\alpha^3 \frac{1}{3} \left(1 - \frac{3}{2} \sin^2\delta_0\right) \sin^2 1''$$

$$Y - \Delta\delta = \Delta\alpha^2 \,.\, \frac{1}{4} \sin 2\delta_0 \sin 1'' + \Delta\alpha^2\Delta\delta \,.\, \frac{1}{2} \cos 2\delta_0 \sin^2 1'' + \Delta\delta^3 \,.\, \frac{1}{3} \sin^2 1''$$

The two were required to agree within 0.02″ in their values of $X \sec \delta_0$ and Y and, in case of this amount of discrepancy, preference was given to Jacoby's formula, for the reason that the limit of accuracy of seven-place logarithms in Turner's formulæ is 0.02″, while Jacoby's formulæ permit the thousandth of a second of arc to be computed.

For about half of the plates corrections were applied to the co-ordinates $x \sec \delta_0$ and y for the second order terms of differential refraction by the use of Turner's formulæ

$$\Delta_2 x \sec \delta_0 = - \mu \sec \delta^0 [H (2 + H^2) x^2 + G (1 + 2H^2) xy + H (1 + G^2) y^2]$$

$$\Delta_2 y = - \mu [G (1 + H^2) x^2 + H (1 + 2G^2) xy + G (2 + G^2) y^2]$$

in which μ is the constant of refraction, $G = \tan \zeta_0 \cos q$ and $H = \tan \zeta_0 \sin q$, ζ_0 and q being the zenith distance and parallactic angle at the center of the plate. Three small tables were prepared which gave the co-efficients of x^2, xy and y^2 in these formulæ with the arguments G and H, greatly simplifying the computations. When the zenith distance was less than 30° these corrections were found to be less than 0.01″ and were therefore neglected.

The first order terms of differential refraction, together with those of precession, nutation and aberration, being linear in form, were considered as producing errors of the scale value and

TABLE I.

POSITIONS OF EROS, COMPARED WITH THE EPHEMERIS IN CIRCULAR No. 9.

Plate No.	Central Standard Time. 1900.	h	m	s	Apparent R. A. h	m	s	Apparent Decl. °	′	″	Parallax. R. A. s	Parallax. Decl. ″	O — C Δα s	O — C Δδ ″	No. of Images.
4	Sept. 26	10	17	10.7	2	42	51.200	+43	9	2.12	−0.856	+4.29	+0.038	+1.46	2
5	26	12	40	10.7	2	42	52.894	43	11	21.34	0.451	1.12	−0.005	1.88	2
7	Oct. 5	10	49	27.0	2	43	56.773	46	30	53.65	0.827	2.08	0.071	1.64	2
8	9	8	59	22.0	2	42	54.815	47	54	47.44	1.141	4.97	0.112	2.05	5
9	10	8	48	0.0	2	42	29.314	48	15	26.17	1.173	5.24	0.103	1.69	5
10	10	12	5	2.5	2	42	24.777	48	18	21.38	0.474	−0.50	0.097	1.44	5
11	11	7	59	6.0	2	42	0.539	48	35	15.56	1.245	+6.99	0.117	1.75	5
12	11	12	6	7.0	2	41	54.243	48	38	53.03	0.465	−0.66	0.099	1.80	5
13	12	8	32	20.0	2	41	25.630	48	56	0.22	1.228	+5.48	0.107	1.90	5
14	12	12	23	38.0	2	41	18.907	48	59	19.85	0.367	−1.07	0.086	1.66	7
15	16	7	36	30.7	2	38	26.888	50	12	40.85	1.362	+7.13	0.144	1.43	5
16	16	11	19	12.7	2	38	17.775	50	15	41.03	0.638	−0.76	0.113	1.72	9
16	16	11	53	32.7	2	38	16·253	50	16	7.87	0.449	−1.37	0.139	1.50	2
17	18	8	21	39.8	2	36	27.542	50	49	29.60	1.333	+4.67	0.154	1.62	7
18	18	11	30	56.8	2	36	18.379	50	51	54.32	0.542	−1.38	0.158	1.68	15
19	19	8	3	41.4	2	35	22.781	51	6	37.39	1.382	+5.23	0·175	1.75	5
20	19	12	32	44.4	2	35	8.763	51	9	55.97	0.139	−2.24	0.174	1.70	7
20a	23	7	51	44.5	2	30	16.219	52	10	15.84	1.459	+4.80	0.210	1.65	5
20b	23	12	40	46.5	2	29	57.452	52	13	19.46	+0.040	−2.75	0.222	1.47	3
21	24	8	36	24.2	2	28	45.660	52	25	5.60	−1.335	+2.54	0.217	1.23	5
22	24	12	3	57.2	2	28	31.480	52	27	11.85	0.168	−2.80	0.226	1.45	7
23	25	7	48	41.2	2	27	17.041	52	38	16.25	1.487	+4.41	0.209	1.46	5
24	26	7	34	44.5	2	25	42.296	52	51	5.28	1.530	4.81	0.229	1.72	5
25	Nov. 1	7	38	50.6	2	14	56.198	53	51	55.41	1.506	3.20	0.275	1.15	5
26	2	7	9	54.0	2	13	1.460	53	58	50.72	1.639	+4.05	0.319	0.97	5
27	7	9	19	20.3	2	2	41.037	54	20	11.39	0.853	−2.54	0.347	0.33	6
28	8	8	56	51.4	2	0	39.306	54	21	19.43	0.983	−2.10	0.351	0.89	1
29	10	5	56	20.3	1	56	49.081	24	20	35.49	1.845	+5.69	0.255	0.52	1
30	13	6	8	22.6	1	50	46.350	54	12	2.19	−1.793	+4.16	0.283	+0.15	5
31	13	11	34	26.0	1	50	17.386	54	11	8.15	+0.525	−3.64	0.314	−0.14	5
32	13	16	45	33.5	1	49	50.685	54	9	52 16	1.962	+10.72	0.294	−0.09	5
33	14	17	29	32.0	1	47	51.735	54	4	15.47	1.888	13.91	0,355	+0.32	4
34	14	17	48	18.0	1	47	50.327	54	4	9.80	+1.845	15.00	−0.321	0.38	2

35		15	5	47	33.3	1	46	57.428	54	1	14.23	− 1.842	+ 4.79	− 0.335	+ 0.32	5
36		22	6	45	27.0	1	35	23.451	52	51	40.63	− 1.402	0.29	0.349	− 0.42	5
37		22	17	21	30.2	1	34	44.722	52	45	30.90	+ 1.819	17.06	0.345	0.02	5
38		24	6	17	34.8	1	32	53.067	52	23	58.55	− 1.509	+ 1.28	0.345	0.58	5
39		26	7	48	35.8	1	30	40.611	51	51	52.39	− 0.791	− 2.26	0.319	0.56	5
41		26	17	23	15.0	1	30	15.689	51	44	56.11	+ 1.724	+ 18.83	0.348	0.50	5
42		29	6	22	43.0	1	28	20.468	51	0	43.03	− 1.317	0.53	0.308	0.61	4
43		29	16	58	42.7	1	28	1.261	50	52	15.17	+ 1.760	18.62	0.246	0.47	5
44		30	6	8	43.4	1	27	46.067	50	42	14.14	− 1.375	+ 1.06	0.280	0.62	4
45	Dec.	4	7	27	58.5	1	26	33.061	49	20	55.79	0.665	− 1.55	0.363	0.94	4
47		8	5	57	22.1	1	27	9.074	47	54	33.09	1.203	+ 1.39	0.271	0.90	4
48		11	5	45	48.4	1	28	43.792	46	45	6.74	1.194	1.94	0.286	0.79	4
49		12	6	0	41.0	1	29	28.569	46	21	4.03	1.067	1.45	0.275	0.46	5
50		18	5	54	29.5	1	36	3.295	43	53	29.01	− 0.959	2.20	0.260	0.83	5
51		18	15	28	59.6	1	36	34.393	43	42	9.55	+ 1.698	19.27	0.289	0.46	2
52		19	5	43	59.6	1	37	29.046	43	28	26.83	− 1.007	2.65	0.282	0.52	5
53		19	14	47	6.4	1	38	0.238	43	18	39.69	+ 1.781	17.10	0.322	0.64	3
54		20	7	35	7.5	1	39	7.458	43	1	10.80	− 0.158	0.62	0.264	0.70	5
55		21	6	16	59.6	1	40	40.457	42	37	5.00	− 0.734	1.96	0.220	1.08	2
56		25	9	54	34.0	1	48	19.758	40	50	37.64	+ 0.871	3.37	0.281	1.11	4
57		28	10	0	4.8	1	54	45.866	39	33	9.00	+ 0.999	4.63	0.244	1.08	5
59		31	6	9	5.8	2	1	29.336	38	19	51.57	− 0.616	3.72	0.189	1.11	5
	1901.															
60	Jan.	1	5	49	12.2	2	3	56.700	37	53	23.50	0.736	4.31	0.238	1.24	5
61		2	6	3	10	2	6	31.314	37	28	20.23	0.628	4.18	− 0.224	− 1.31	4
62		14	6	3	58.8	2	41	27.586	32	20	6.13	0.495	6.18	+ 0.036	+ 0.84	3
63		15	5	58	39.2	2	44	39.727	31	54	42.07	0.521	6.43	0.000	0.09	1
65		18	6	6	13.0	2	54	33.000	30	38	25.56	0.451	6.81	+ 0.025	1.01	3
67		21	7	7	23.1	3	4	52.310	29	21	42.07	0.047	6.87	+ 0.043	0.69	5
68		24	6	44	38.3	3	15	16.316	28	7	1.75	− 0.178	7.21	− 0.002	0.57	3
69		29	7	49	48.5	3	33	19.649	26	2	16.72	+ 0.229	8.21	+ 0.060	0.15	3
70	Feb.	2	7	15	56.0	3	47	52.425	24	25	26.74	+ 0.032	9.04	0.021	+ 0.21	7
72		5	6	56	2.2	3	58	55.022	23	13	41.95	− 0.077	9.00	0.040	− 0.35	4
73		11	7	25	53.6	4	21	21.541	20	52	0.53	+ 0.094	9.69	0.048	0.31	7
74		12	7	17	53.8	4	25	4.779	20	29	1.74	0.052	9.70	0.006	0.66	7
75		14	7	57	56.2	4	32	40.099	+ 19	42	35.35	+ 0.259	+ 10.01	+ 0.013	− 0.70	7

of the orientation of the plate, and were partly corrected by the adjustment of the plate in the measuring machine. The remaining errors were adjusted by means of a least square solution of equations for each star of the form

$$a + bx + cy = n$$
$$\alpha + \beta x + \gamma y = \nu,$$

in which n is the difference between the computed and the observed $x \sec \delta_0$, and ν the corresponding difference for the y co-ordinates, a, b, c, α, β, and γ being unknown constants to be determined. This required for the 67 plates 134 least square solutions and, including a number of preliminary solutions in which the measures of the different images were reduced separately and a few plates which were measured a second time, the least square solutions numbered over 150.

As soon as the constants a, b, c, etc., were determined their values substituted in equations of the same form gave the corrections to be applied to the measured co-ordinates of the stars and the planet in order to give the correct co-ordinates for the year 1900.0. These corrections to the star places agree remarkably well from plate to plate, showing that the star places obtained from the photographs are very exact. They also show by their smallness that the mean of the meridian circle observations at the thirteen observatories comes very near to the true position of a star. In very few cases is the difference as great as 1″.

It yet remains to convert the co-ordinates of the planet into differences of right ascension and declination, and apply them to the right ascension and declination of the center of the plate, reduce these for precession, nutation and aberration up to the moment of the observation, calculate the approximate parallax of Eros at that moment, assuming the solar parallax to be 8″.8, and the places of Eros are ready to be compared with the ephemeris of Professor Millosevich. All this takes but a minute to write but it took several days of very careful computation. The results are shown in Table I.

In this table the residuals in the two columns next to the last agree extremely well. We are accustomed in ordinary micrometric observations of asteroids to see differences of tenths of seconds of time and of several seconds of arc between residuals close together, but here they are only 2 or 3 hundredths of seconds of time and 1 or 2 tenths of seconds of arc.

TABLE II.

COMPARISON OF RESIDUALS IN RIGHT ASCENSION FROM THE PHOTOGRAPHS AT NORTHFIELD, PARIS AND BORDEAUX.

Date.		Gr. M. T. h	m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Oct.	3	8	48	— 0.957		— 0.051		— 0.060	+ ·009
		10	13	0.798		.044		.060	+ .016
	5	9	09	0.951		.074		.069	— .005
		16	49	0.827	— .071			.070	— .001
	6	8	38	1.008		.048		.073	+ .025
		10	51	0.685		.105		.073	— .032
	8	10	46	0.700		.080		.083	+ .003
	9	11	07	0.614		.088		.089	+ .001
		11	19	0.564		.090		.089	— .001
		14	59	1.141	.112			.090	.022
	10	10	56	0.653		.103		.094	.009
		14	48	1.173	.103			.095	.008
		18	5	0.474	.097			.096	.009
	11	13	59	1.245	.117			.101	— .016
		18	6	0.465	.099			.102	+ .003
	12	10	43	0.694		.113		106	— .007
		14	32	1.228	.107			.107	.000
		18	24	0.367	.086			.108	+ .022
	15	7	16	1.330			— .135	.125	— .010
		7	46	1.308			.112	.125	+ .014
		15	58	+ 0.939			.144	.128	— .016
		16	18	1.019			.123	.128	+ .005
		16	32	1.017		.129		.128	— .001
		16	50	1.132			.126	.128	+ .002
		16	59	+ 1.096		.110		.128	.018
	16	10	34	— 0.702		.131		.133	+ .002
		13	36	1.362	.144			.134	— .010
		17	19	.638	.113			.135	+ .022
		17	53	.449	.139			.135	— .004
	17	10	26	.729		.140		.140	.000
		11	11	— .509		.112		.141	+ .029
		14	17	+ .512		.127		.142	.015
		15	12	.778		.134		.142	+ .008
		16	11	+ 1.017		.171		.143	— .028
	18	7	54	— 1.349			.137	.149	+ .012
		14	22	1.333	.154			.151	— .003
		17	31	0.542	.158			.154	— .003
	19	7	9	1.420			.145	.158	+ 0.13
		7	30	1.399			.163	.158	— .005
		9	49	0.877		.154		.159	+ .005
		14	04	— 1.382	.175			.161	— .014
		14	29	+ 0.645		.138		.161	+ .024
		15	29	0.926		.162		.161	— .001
		16	29	1.144		.128		.161	+ .033
		16	30	1.209			.161	.161	.000
		16	51	+ 1.276			.149	.161	+ .012
		18	33	— 0.139	— .174			.162	— .012
	20	8	22	— 1.306			.177	.169	.008
	21	16	24	+ 1.266			.194	.184	— .010
		16	45	1.332			.168	.185	+ .017
		17	5	+ 1.388			— .211	.185	— .026
	22	7	50	— 1.288		.202		.192	.010
		8	10	1.236		.207		.192	.015
		10	40	0.586		.217		.193	.024
		11	0	— 0.473		.197		.193	.004
		14	07	+ 0.642		.214		.194	.020
		15	07	0.943		.195		.194	.001
		16	09	+ 1.180		— .210		— .195	— .015

TABLE II.—Continued.

Date.		Gr. M. T. h	m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Oct.	22	17	02	+ 1.415			— .190	— .196	+ .006
	23	7	49	— 1.298		— .181		.204	0.23
		8	11	1.238		.178		.204	+ .026
		13	52	— 1.459	— .210			.206	— .005
		14	03	+ .660		.188		.206	+ .018
		15	3	.965		.208		.206	— .002
		16	3	1.205		.225		.207	.018
		18	41	+ 0.040	.222			.208	.014
	24	7	40	— 1.453			.242	.215	— .027
		14	36	1.297	.217			.218	+ .001
		18	4	0.168	.226			.220	— .006
	25	7	48	1.440			.240	.228	— .012
		13	49	— 1.487	.209			.230	+ .021
		16	15	+ 1.317		.248		.232	— .017
	26	9	51	— 0.779		.230		.241	+ .011
		10	11	.666		.214		.241	.027
		13	35	— 1.530	.229			.242	.013
		13	53	+ .729		.220		.242	.022
		14	51	1.032		.230		.243	.013
		15	51	+ 1.277		.227		.243	.017
	27	7	57	— 1.290		.247		.252	.005
		8	17	1.217		.233		.252	.019
		11	20	— 0.204		.248		.253	+ .005
		14	6	+ 0.845		.256		.255	— .001
		15	48	1.306		.250		.256	+ .006
		16	48	1.462		.264		.256	— .008
	29	17	10	1.661			.293	.276	— .016
		17	28	+ 1.678			.261	.276	+ .015
	30	6	30	— 1.660			.306	.280	— .026
		16	8	+ 1.476		.263		.284	+ .021
		16	50	1.665			.286	.285	— .001
		16	55	1.562		.277		.285	+ .008
		17	16	+ 1.696			.292	.285	- .007
Nov.	1	5	48	— 1.607		.278		.295	+ .017
		13	39	1.506	.275			.297	+ .022
	2	13	10	- 1.639	.319			.304	— .015
	3	16	51	+ 1.780			— .312	.309	.003
	7	5	39	— 1.683		.328		.320	— .008
		7	48	1.219		.308		.320	+ .012
		8	8	1.108		.304		.320	.016
		9	4	0.748		.306		.320	.014
		9	29	— 0.574		.302		.320	.018
		11	7	+ 0.154		.291		.320	+ .029
		15	19	— 0.853	.347			.320	— .027
		5	47	1.670		.316		.322	+ .006
	8	7	57	1.147		.329		.322	- .007
		8	41	0.873		.301		.322	+ .021
		9	38	0.475		.303		.322	+ .019
		14	57	0.983	.351			.323	— .028
	10	5	36	1 697		.301		.334	+ .023
		10	24	— 0.035		.311		.324	.013
		10	33	+ 0.035		.311		.324	+ .013
		10	42	+ 0.104		.332		.324	— .008
		11	56	- 1.845	.255			.324	(+ .069)
	11	6	10	1.596		.327		.326	— .001
		7	9	1.341		.329		.326	- .003
	13	12	8	— 1.793	.283			.328	+ .045
		16	44	+ 1.789		.335		.328	— .007
		17	21	1.723		— .347		.328	— .019
		17	34	+ 0.525	— .314			— .328	+ .014

TABLE II.—Continued.

Date.		Gr. M. T.		Parallax.	Northfield.	Paris.	Bordeaux.	Graphic Correction.	v.
		h	m	s	s	s	s	s	s
Nov.	13	23	46	+ 1.962	— .294			— .328	+ .043
	14	23	30	1.888	.355			.329	— .026
		23	48	1.845	.321			.329	+ .008
	15	10	11	0.092		— .319		.329	.010
		10	20	0.167		.319		.329	.010
		10	29	+ 0.238		.313		.329	+ .016
		11	48	— 1.842	.335			.329	— .006
	22	12	45	— 1.402	.349			.334	.005
		23	22	+ 1.819	.345			.333	.012
	24	12	18	— 1.509	.345			.328	— .017
	26	13	49	— 0.791	.319			.323	+ .004
		16	27	+ 1.880			— .313	.323	+ .010
		23	23	+ 1.724	.348			.322	— .026
	29	12	23	— 1.317	.308			.315	+ .007
		22	59	+ 1.760	.246			.314	.068
	30	5	54	— 1.386			.288	.313	.025
		12	9	— 1.375	.280			.312	.032
		15	49	+ 1.916			.230	.312	.082
		16	12	+ 1.855			.205	.312	+ .107
Dec.	4	13	28	— .665	.363			.303	— .060
	8	11	57	1.203	.271			.290	+ .019
	11	11	46	1.194	.286			.282	— .004
	12	12	1	— 1.067	.275			.280	+ .005
	17	12	18	+ 1.695			.237	.266	.029
	18	11	54	— 0.959	.260			.263	+ .003
		21	29	+ 1.698	.289			.261	— .028
	19	11	44	— 1.007	.282			.260	.022
		12	16	+ 1.682			.260	.260	— .000
		13	19	1.805			.240	.259	+ .019
		14	23	1.791			.263	.259	— .004
		20	47	+ 1.781	.322			.259	(— .063)
	20	13	35	— 0.158	.264			.257	— .007
	21	12	17	— 0.734	.220			.254	+ .034
	24	11	47	+ 1.576			.224	.246	.022
		12	23	1.680			.228	.246	+ .018
	25	15	55	0.871	.281			.242	— .039
	28	16	0	+ 0.999	.244			.234	— .010
	31	12	9	— 0.616	.189			.225	+ .036
Jan.	1	11	49	0.736	.238			.222	— .016
	2	12	3	— 0.628	.224			.210	.004
	4	12	14	+ 1.580			.218	.214	— .004
		12	52	1.625			— 185	— .214	+ .029
	5	11	36	1.481			+ .011	+ .030	— .019
		12	10	1.564			.021	.030	— .009
	9	11	18	1.400			.090	.030	+ .060
		12	20	1.546			+ .052	.030	+ .022
	14	11	23	1.380			— .013	.030	— .043
		11	53	+ 1.454			+ .006	.030	— .024
		12	4	— 0.495	+ .036			.030	+ .006
		12	34	+ 1.515			.066	.030	+ .036
	15	11	59	— 0.521	.000			.030	— .030
	18	12	6	— 0.451	.025			.030	.005
	21	11	20	+ 1.313			.011	.030	.019
		12	10	+ 1.417			+ .010	.030	— .020
		13	7	— 0.047	+ .043			.030	+ .013
	22	10	57	+ 1.237			— .005	.030	— .035
		11	22	+ 1.310			+ 0.003	.030	— .027
	24	12	45	— 0.178	— .002			+ .030	— .032

TABLE II.—Continued.

Date.		Gr. M. T. h	Gr. M. T. m	Parallax. s	Northfield. s	Paris. s	Bordeaux. s	Graphic Correction. s	v. s
Jan.	29	13	50	+ 0.363	+ .060			+ .030	+ .030
Feb.	2	13	16	+ 0.032	.021			.030	— .009
	5	12	56	— 0.077	.040			.030	+ .010
	11	11	17	+ 1.119			— .037	.030	— .067
	11	13	26	0.094	.048			.030	+ .018
	12	13	18	0.052	.006			.030	— .024
	13	10	37	0.999			+ 0.045	.030	+ .015
	14	10	31	0.973			0.041	.030	+ .011
		13	58	0.259	+ .013			.030	— .017
	21	9	42	0.759			0.046	.030	+ .017
	22	9	0	0.590			0.063	.030	.033
	23	11	30	+ 1.036			+ 0.048	+ 0.030	+ .018

In Table II I have put side by side the residuals in right ascension obtained from the photographs taken during the same interval of time at Northfield, Paris and Bordeaux, those of Paris and Bordeaux being the only photographic results which have as yet come to hand. These results were published in Circular No. 10 of the International Conference. The agreement of the three sets of residuals is on the whole quite satisfactory. In the diagram Fig. 7 I have platted these residuals from Oct. 3 to Nov. 15, the period during which the seeing seems to have been best at all the observatories. The numbers at the left end of the diagram are thousandths of seconds of time. The Northfield observations are represented by full black circles, those at Paris by open circles and those at Bordeaux by crosses. In this graphic way their relative accuracy and close agreement is well shown to the eye.

The reader must understand that the residuals are principally due to the errors of the elements of Eros' orbit, from which the ephemeris was computed. The third column of the table gives the amount of the parallax correction which was applied to the observation, and nowhere does the residual change sign, or even change by any marked amount, when the parallax correction changes sign. It is at once apparent that there can be no great correction to the assumed value 8.8″ of the solar parallax.

Up to this point I have endeavored to use as exact methods as I could employ. In what follows the process used is only approximate, but is as accurate as it is worth while to use in this preliminary investigation.

In order to eliminate the effect of the errors of the ephemeris I have drawn a smooth line as near as I could through the mean of all the platted points and have read off from this line the corrections for each date. These are entered in the column headed "graphic correction." The final residuals v are still vitiated to a slight extent by a possible correction to the ephemeris but con-

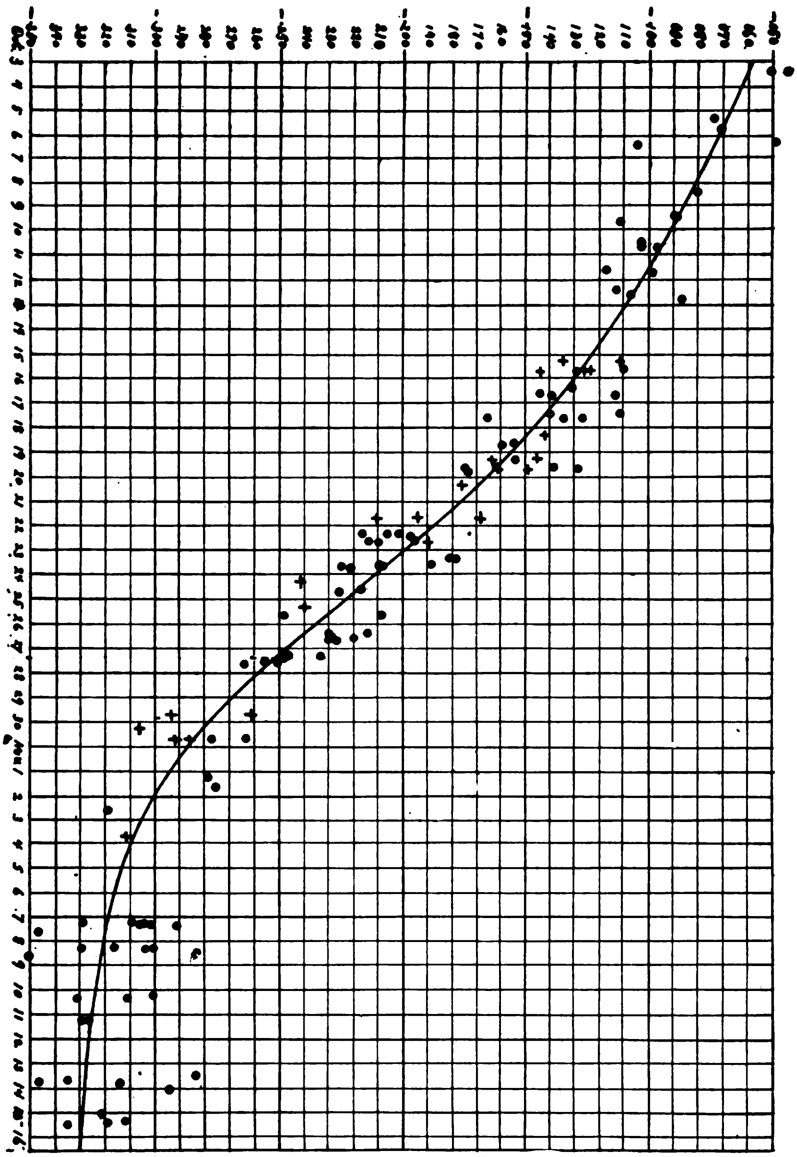


FIG. 7. GRAPHICAL COMPARISON OF THE RIGHT ASCENSIONS OF EROS FROM THE PHOTOGRAPHS AT NORTHFIELD, PARIS AND BORDEAUX.

sist mainly of accidental errors of the measures, and by taking the differences between suitable observations close together one may form equations which contain only the one unknown quantity besides the accidental errors. If we divide the numbers in the column headed "parallax" by 8''.8 we shall have the parallax factor or co-efficient, by which the correction to the parallax constant should be multiplied in each case. To save time we may regard $\frac{\Delta\pi}{8''.8}$ as the unknown sought and so take the numbers in the column of parallax as its co-efficients. Subtracting the co-efficients and residuals on Oct. 9 and 10 we will thus get the equation

$$0.667^{s}\,\frac{\Delta\pi}{8''.8} = +\,0.013^{s}$$

In the following table are given all the similar equations which I could form from the Northfield results:

APPROXIMATE PARALLAX EQUATIONS, NORTHFIELD.

Date.	s		s	Date.	s		s
Oct. 9-10	0.667	$\frac{\Delta\pi}{8.8''}$ =	+ 0.013	Nov. 22	3 221	$\frac{\Delta\pi}{8.8''}$ =	− 0.007
10-11	0.771	"	+ .007	26-26	2.515	"	− .030
11-11	0.780	"	.019	29-29	3.077	"	+ .061
11-12	0.763	"	.003	29-30	3.135	"	+ .036
12-12	0.861	"	.022	Dec. 18-18	2.657	"	− .031
16-16	0.818	"	+ .019	18-19	2.705	"	.006
18-18	0.791	"	.000	19-19	2.788	"	.041
18-19	0.840	"	+ .011	19-20	1.939	" =	− .058
19-19	1.243	"	+ .002				
23-23	1.499	"	− .009		22.037		+ .097
23-24	1.337	"	.015				− .173
24-24	1.129	"	.007				
24-25	1.319	"	.027				− .076
Nov. 13-13	2.318	"	− .031				
13-13	1.437	"	+ .020				
14-15	3.708	" =	− .003				
	20.281		+ .116				
			− .092				
			+ .024				

Solution, Oct. 9-Nov. 15.

$$20.281\,\frac{\Delta\pi}{8.8''} = +\,0.024$$

$$\Delta\pi = +\,0.010''$$

Solution, Oct. 9-Dec. 20.

$$42.418\,\frac{\Delta\pi}{8.8''} = -\,0.052$$

$$\Delta\pi = -\,0.011''$$

Solving the equations from Oct. 9 to Nov. 15 gives for $\Delta\pi$, the correction to the assumed solar parallax, $+\,0''.010$ or, taking the entire list, $-\,0''.011$. It will be seen that if one of the large residuals were omitted the correction to the parallax constant would be changed by its entire amount, so that the above figures simply indicate the range within which it must lie, without giving its actual amount.

The following equations were obtained from the Paris and Bordeaux residuals in the same manner.

APPROXIMATE PARALLAX EQUATIONS, PARIS.

Date.		s			s
Oct.	15-16	1.758	$\frac{\Delta\pi}{8.8''} =$	+	.006
	17-17	1.241	"	+	.015
	17-17	1.287	"	—	.021
	19-19	1.782	"	+	.014
	22-22	1.904	"	—	.008
	22-22	1.529	"	+	.023
	22-22	1.653	"	—	.011
	23-23	2.090	"		.034
	23-23	2.300	"		.041
	23-23	2.106	"		.015
	23-23	2.323	"		.037
	25-26	2.039	"	—	.037
	26-26	1.659	"	+	.007
	26-26	1.820	"	—	.012,
	26-27	2.019	"	+	.017
	26-27	2.239	"	—	.006
	26-27	1.481	"	+	.012
	27-27	2.135	"	—	.006
	27-27	2.523	"		.013
	27-27	1.666	"	—	.013

		s			s
Nov.	7- 7	0.935	$\frac{\Delta\pi}{8.8''} =$	+	.022
	7- 7	0.645	"	+	.006
	7- 7	1.262	"		.013
	7- 8	1.301	"		.036
	8- 8	0.672	"	+	.026
	10-10	1.730	"	—	.017
	10-11	1.596	"	+	.014
	10-11	1.445	"	—	.005
		47.140		+	.211
				—	.276
				—	.065

Solution.

$$47.140 \frac{\Delta\pi}{8.8''} = - .065$$
$$\Delta\pi = - .012''$$

APPROXIMATE PARALLAX EQUATIONS, BORDEAUX.

Date.		s			s
Oct.	15-15	2.309	$\frac{\Delta\pi}{8.8''} =$	+	.005
	15-15	2.440	"	—	.012
	19-19	2.629	"	—	.013
	19-19	2.675	"	+	.017
	19-20	2.548	"		.014
	20-21	2.630	"		.002
	29-30	3.330	"		.026
	30-30	3.340	"	+	.022
		21.901		+	.086
				—	.025
				+	.061

Solution.

$$21.901 \frac{\Delta\pi}{8.8''} = + .061$$
$$\Delta\pi = + .024''$$

In the equations which follow, formed by combining the residuals of the different observatories on the same date, there may be systematic errors resulting from different methods of averaging the star-places obtained with the thirteen meridian circles. I took the arithmetical mean without assigning any weights, while at Paris and Bordeaux they must have assigned different weights to the different observations, for seldom do two of the three agree exactly on any star. The differences are of about the same magnitude as the final residuals for Eros and, although they are systematic for individual stars and for any one night, or perhaps two or three nights in succession, yet in the long run they may be regarded as accidental errors and so eliminated in average of a great number of equations. The comparison of 85 star places determined from the photographs at both Paris and

Northfield, and 123 determined at both Bordeaux and Northfield, gave as the average difference

Paris—Northfield	in R. A. $+ .005^{s}$,	in Decl, $+ .003''$
Bordeaux—Northfield	" $- .002$	" $+ .003$

APPROXIMATE PARALLAX EQUATIONS, PARIS-NORTHFIELD.

Date.	s		s	Date.	s		s
Oct. 9	0.577	$\frac{\Delta\pi}{8.8''} =$	$+ .021$	Nov. 7	1.007	$\frac{\Delta\pi}{8.8''} =$	$+ .056$
12	0.534	"	$- .007$	13	3.582	"	$- .052$
16	0.660	"	$+ .022$	13	1.198	"	$- .033$
19	2.287	"	$.033$	15	2.080	"	$+ .022$
23	2.271	"	$+ .013$				
23	1.165	"	$- .004$		21.572		$+ .187$
25	2.804	"	$- .038$				$- .134$
26	0.864	"	$+ .014$				
26	2.543	"	$+ .006$				$+ .053$

Solution.

$$21.572 \frac{\Delta\pi}{8.8''} = + .053$$

$$\Delta\pi = + .022''$$

APPROXIMATE PARALLAX EQUATIONS, BORDEAUX-NORTHFIELD.

Date.	s		s
Oct. 19	1.380	$\frac{\Delta\pi}{8.8''} =$	$+ .018$
Nov. 26	2.671	"	$+ .006$
Dec. 19	2.689	"	$+ .022$
Jan. 14	1.949	"	$- .030$
14	2.000	"	$+ .030$
21	1.412	"	$- .033$
Feb. 14	0.714	"	$+ .028$
	12.815		$+ .104$
			$- .063$
			$+ .041$

Solution.

$$12.815 \frac{\Delta\pi}{8.8''} = + .041$$

$$\Delta\pi = + .028''$$

If now we take the arithmetical mean of the five different values of $\Delta\pi$ which have been obtained we shall get $\Delta\pi = + 0.010''$, with a probable error of $\pm 0.006''$. If we give the different values weights in proportion to the co-efficients of the final equations from which they were derived, we shall get $\Delta\pi = + 0.002'' \pm 0.006''$.

The only conclusion which we can draw from these results is that the solar parallax is very near to 8,80″, probably between that and 8.81″. It would not be worth while to undertake a rigorous solution of these equations alone, for it is necessary to get together a much greater mass of observations in order to more completely eliminate the accidental errors.

I have made a similar study of the residuals in declination and find that they give a larger positive correction to the parallax, but the co-efficients are too small to give them much weight in comparison with the right ascension residuals.

It is interesting to note that the results obtained above from the right ascension residuals agree very closely with those obtained by Dr. Gill, of the Cape Observatory, from Heliometer measures of the asteroids Victoria and Sappho in 1889. In fact the value 8.802″ is identical to the last figure with the most probable value found by Dr. Gill, and the probable error resulting from the approximate method which I have used is less than 0.001″ greater than his. We may therefore confidently expect that, when all the observations at forty or more observatories are combined by the most refined methods, the solar parallax will be determined more accurately than ever before.

If we assume 8.80″ as the correct parallax of the Sun, and 3963.3 miles as the equatorial radius of the Earth, the Sun's distance is given by the proportion

$$d : 3963.3 :: 1 : 8.80 \sin 1'',$$

which solved gives $d = 92{,}897{,}000$ miles. If the parallax should be increased to 8.81″ the distance would be decreased by 106,000 miles. There is still therefore an uncertainty of about 60,000 miles in the Sun's distance. This uncertainty we may perhaps expect to be diminished by half when the final result is obtained from the Eros observations of 1900-1901.

WHAT WOMEN HAVE DONE FOR ASTRONOMY IN THE UNITED STATES.

ANNE P. McKENNEY.

FOR POPULAR ASTRONOMY.

The United States of America is a large country with large hearted and liberal minded people. There is no other country in the world where women, as a class, have advanced so rapidly. In their studies they encounter very little narrow mindedness and jealousy among their fellow-workers in the same field of research, but, in general, are treated with the greatest courtesy, encouragement and assistance. While we cannot maintain that in everything woman is man's equal, yet in many fields of work her patience, perseverance and method make her his superior.

In no line of work has her influence been felt more than in the field of astronomy. A review of the progress of astronomical research during the past century is incomplete without a distinct recognition of woman's activity in furthering the science, not only by actual work but also by substantial pecuniary assistance.

Maria Mitchell: the first American woman astronomer, was

born on the island of Nantucket, Mass., August 1, 1818, of a Quaker family. She was raised in an intelligent home where topics of the day were fully discussed. Matters of science received special attention. Her father owned an excellent telescope and was himself a very good astronomer, being able to carry on independent observations. Miss Mitchell early displayed her delight in astronomy. She was her father's apt pupil, supplementing his instruction with diligent study. At eighteen she became librarian of the Nantucket Athenaeum, which place she held for twenty years. During this time she pursued her scientific studies with great ardor. In 1847 her patient work was rewarded by the discovery of a new comet, for this, Frederick of Denmark rewarded her with a gold medal. The Cantons of Switzerland voted her a similar recognition of her services. She was subsequently employed by the government to do much difficult mathematical work on the coast survey and also helped in the preparation of the "American Nautical Almanac." In 1857 she went abroad and made the tour of the celebrated observatories of Europe. Here she was given a hearty welcome by foreign astronomers and her abilities recognized and honored by membership in many scientific societies being conferred upon her. Her fame early opened for her all the doors in social as well as scientific circles.

During her absence in Europe, her American friends, under the leadership of Elizabeth Peabody of Boston, built an observatory for her use in Nantucket and fitted it with a fine telescope. Here she pursued her investigations until Vassar College was opened in 1865, when she was called to the professorship of Astronomy in that institution and was also given the directorship of the Vassar Observatory. She at once demonstrated her abilities as a teacher, and her earnestness and simplicity were not without their effect on the college at large. While at Vassar she made observations of the surface details of Jupiter and Saturn, and of the positions of their satellites. She made also many other observations of comets, etc. Her main force, however, went into teaching. In 1888 she resigned her position in the college owing to ill health and advancing years, and wishing to devote herself to special investigation. After leaving Vassar she returned to her family in Lynn, Mass. There she had moved her astronomical instruments. She was the first of her sex elected to membership by the American Academy of Arts and Sciences. American Colleges conferred degrees upon her. For several years she edited the astronomical notes in the *Scientific American* which were based on calculations made by her students. She died at Lynn,

Mass., June 28, 1889.

Williamina Paton Fleming: was born in Dundee, Scotland, May 15, 1857. She was the daughter of Robert Stevens, a picture dealer. She received her early education in her native town in the public schools, in which she subsequently taught for five years. In 1877 she married James Orr Fleming of Dundee, Scotland.

On coming to the United States she became connected with the Harvard Observatory, one department of which she is at present in charge. Beginning with the simplest forms of computations the responsibility of her position increased every year, until now she has a splendid record as an astronomer. She has charge of a corps of women assistants by whom the stars are studied in the daytime by the aid of photography, in the same way as by night through the telescope, and by whom the observations made by the meridian photometer since 1888 have been discussed. Mrs. Fleming from her examination of the spectra of stars, of which she has examined over a million, has achieved distinction as a discoverer, having increased the number of known stars whose spectrum is of the third type, from about 1,000 to 3,000; while of the rare class of stars of the fifth type the number has been raised from 16 to 67. "At no other observatory have any stars of the last mentioned class been discovered, during the last eleven years" says Professor Pickering. She has furthermore discovered 54 *new* variable stars by means of the bright hydrogen lines in their spectra, and in each case has proved their variability from photographic charts of the same regions. In 1890 she was able to announce, from its spectrum, that a certain star in the constellation Cygnus was variable. She also has the honor of having first discovered planetary nebulæ by the aid of photography, while in 1893 and 1895 she made the remarkable discoveries of new stars in the constellations Norma and Carina. Besides numerous contributions to astronomical periodicals she has aided in the preparation of several volumes of the *Annals of the Observatory;* Her signature has appeared from time to time in the *Astronomische Nachrichten* and other astronomical journals. Her name is well known among European scientists. *The Observatory* has called her a brilliant discoverer.

Alice Lamb: now Mrs. Milton Updegraff was assistant astronomer in the Washburn Observatory from June 1885 to September 1887. Here she had charge of the extensive time service of the Observatory, and also took part in the regular series of observations with the Repsold meridian circle. She made many

observations of the minor planets and double stars with the 15.5 inch equatorial telescope. In September 1887 she married Professor Updegraff and went with him to the Argentine Republic where they both served as astronomers in the National Observatory from November 1887 to March 1890. She had charge of the time service there.

Since returning to the United States she has retained her interest in astronomy and is now preparing for publication a translation of Ruhlmann's "Barometrische Hohemessengen."

Dorothea Klumpke: was born in San Francisco, but left there in her youth and spent several years in Germany, Switzerland and Paris. In 1887 she was a student at the Observatory of Paris, and acted as a translator for the first Astrophotographic Congress which convened in 1887. Her observations of several minor planets and of the Tempel-Swift comet have been published. On December 23, 1893, Miss Klumpke sustained her doctorate thesis before Darbonx Jesse and Andoyer. It was a purely theoretical study of the rings of Saturn. At the conclusion of the examination Darbonx remarked "Your thesis is the first which a woman has presented and successfully maintained with our faculty to obtain the degree of doctor of mathematical sciences. You worthily open the way, and the faculty votes unanimously to declare you worthy of obtaining the degree of 'doctor.'" Dr. Klumpke is now at the head of the bureau for the measurements of the plates of the Astro-photographic Catalogue at the Paris Observatory.

Charlotte R. Willard: graduated at Smith in 1887. There she specialized in astronomy and mathematics. After graduation she accepted a position as assistant at Goodsell Observatory, Northfield, Minn. Here under the direction of Professor Payne she took charge of the time service which is one of the most extensive in this country covering a distance of 13,000 miles. At 9.57 A. M. the signal goes out, all the switches along the line are turned off, these messages having precedence. By means of a small key attached to necessary wires Miss Willard sent out her record of time over the country. Besides this work she occupied for a long time the position of teacher of mathematics at the same place. In 1893 Miss Willard went to Marsovan, Turkey, to teach in the girls' school there. After a few years of work an epidemic of smallpox broke out to which Miss King of Minneapolis, also a teacher, fell a victim, in spite of diligent nursing and the utmost care on the part of her companions she died. Miss Willard took her place and was very successful in her

work. Miss Willard's writings on astronomy are confined for the most part to articles which have appeared from time to time in POPULAR ASTRONOMY of which she was assistant editor for several years.

Mary Emma Byrd: graduated from the University of Michigan and also from Smith College. For several years she was employed as teacher in a high school. Later she was called to the Observatory at Harvard where she remained for one year. From there she went to Goodsell Observatory at Northfield, Minn. She was employed there for four years until called to the Observatory at Smith College, Northampton, Mass. There she was instructor in mathematics and astronomy and is now Director of the Observatory in that place. Her method is the laboratory method. She says "laborious investigations necessitating telescopes and Observatories are not ones which should engage the attention of the average student at the beginning, but rather the simple observations which teach them how to see and enable them to gather at first hand a store of pleasant astronomical information." She published in 1899 "A Laboratory Manual in Astronomy."

Susan J. Cunningham: is Director of the Observatory of Swarthmore College, Swarthmore, Penn., and also mathematical assistant there. At the beginning of her work she was engaged for a year at Vassar. From there she went abroad and studied in Germany, London and Cambridge. On her return to this country she went to the Lick Observatory, where she remained for some time.

On her return East she visited the Harvard Observatory and did some work there. Her work at Swarthmore is interesting, particularly her experiments with the seismograph, an instrument for recording earth-quakes, and announcing their approach. Her instrument recorded the great earth-quake in the Hawaiian Islands some years ago.

Mrs. Elizabeth Davis: studied mathematics and astronomy at the Johns Hopkins University, Baltimore, Md. Here she met Professor Davis, an astronomer, whom she afterwards married. She was interested in mathematical calculations, but her principal work was her calculations for a number of years and even at the present of the Ephemeres of the Sun for the Nautical Almanac. She also did some miscellaneous work on comet-orbits. From time to time she has done work at the Observatories of Yale, Smith and Goodsell. She at one time held the position of professor of mathematics at the Naval Observatory at Washington.

F. Gertrude Wentworth: graduated from the Boston Universiry. Her work has been for the most part in the direction of astronomical computation of a difficult and refined order, involving a capacity and accomplishment far beyond that required by some of the merely mechanical work. She combines an intelligent appreciation with an expertness in the conduct of elaborate numerical processes of the higher practical astronomy. Her work has not been original or direct and independent investigation, but she has far greater capacity for it than many men who attempt it. Professor S. C. Chandler of Cambridge says of her "She is the most trustworthy computer I ever knew, man or woman." She has contributed several papers to the various astronomical publications.

Rose O'Halloran: represents very well the work done in astronomy by women in the West. She was born in San Francisco, Cal., and has conducted much of her work there. She is known to the world through her numerous articles on the observations of eclipses, meteors, variable stars, etc., which frequently appear in POPULAR ASTRONOMY and other periodicals.

Perhaps the best work done by women is that done in connection with the leading Observatories of the East where women are employed, namely at Vassar, Wellesley, Harvard and Columbia.

The Observatory at Vassar College was built and equipped by the Trustees. The officers are employed primarily for the purposes of instruction, any independent work being entirely voluntary. The first director was Maria Mitchell from 1865 to 1888. Her principal work while there was the observation of the surface details of Jupiter and Saturn and the position of their satellites. She also made observations of different comets. Her main force, however, went into teaching. She was succeeded in 1888 by Professor Mary W. Whitney, her pupil and associate. Miss Whitney began the systematic observations of comets with a filar micrometer and the 12-inch equatorial. She published her observations in 1890, 1892, 1895, etc., in the *Astronomical Journal.* She had no regular assistant until 1895 when Miss Caroline Furness, a pupil of hers was appointed to the position. Miss Furness later went to Columbia, where in 1899 she took her Doctor's degree in astronomy under Professor John K. Rees. Miss Whitney together with Miss Furness began observations of minor planets. The result of these observations were published in the *Astronomical Journal* and in the *Astronomische Nachrichten.* They also published observations of occultations at the

times of the lunar eclipses which appeared in POPULAR ASTRONOMY. Within the past few years the Observatory has undertaken the measurement and reduction of astronomical photographs. The special problem investigated is the cataloguing of stars within 1° of the North pole. The work was executed with the advice and at the suggestion of Professor Jacoby of Columbia University, who provided the necessary plates. A discussion of a further series of plates covering 1° to 20° from the pole is now in progress.

From time to time there have been graduate students who have taken part in the regular observational work. Mary Tarbox published observations of minor planets and is now employed at Columbia University. Alice Davis now Secretary and Librarian at the Allegheny Observatory also published observations of minor planets. Margaret Palmer, computer at Yale, received her astronomical training at Vassar, also Antonia Maurey, who is working in spectroscopic astronomy at Harvard. At present there are three graduate students at the Observatory. One is working on the definitive orbit of a comet, the other one on variable stars. They also published the Ephemerides of long period variables in POPULAR ASTRONOMY every month during 1903. In general the work done at Vassar is similar to that done at several of the smaller German and Italian Observatories.

The Observatory at Wellesley was built and equipped by the enlightened liberality of one of the Trustees, Mrs. John C. Whiten. It has been completed but a few years and therefore, as yet, the record of its astronomical day is short. Special emphasis is laid here upon spectroscopic astronomy; the observation and mapping of spectra gases; the study of spectrum maps and finally the study of star spectra. In the uncertainty of the weather the study and measurement of photographs as applied to all the problems of astronomy is found valuable. The above work is included in the general course in Physical and Descriptive Astronomy of which Miss Sarah F. Whiting, a pupil of Professor Pickering of Harvard, is in charge. The mathematical astronomy is in charge of Miss Ellen Hayes, Professor of applied mathematics. The students in this department take appropriate observations and furnish data for their work in time latitude and orbits. As yet the professors have had no time for outside work, but the field open to them in the future is a broad one. Miss Annie J. Cannon, a pupil of Miss Whitney's, has lately published a volumn of annals on the classification of the smaller stars by their spectra. She has also done continuous work on variable

stars. While employed at the Harvard Observatory she made a detailed study of the spectra of bright southern stars.

The application of photography to astronomy has wonderfully increased the opportunities for women. The most extended application of the aid of women in this speciality has been under the Directorship of Professor Edward Pickering at the Harvard Observatory where a large force of women are constantly employed under the supervision of Mrs. Williamina Fleming. She is in charge of the department for the examination of views and of photographic plates taken with the Draper telescope. In the course of this examination Mrs. Fleming has made a large number of discoveries of variables and has confirmed the discovery of several new stars. Mrs. Fleming is ably assisted in this work by Miss E. F. Leland and Miss A. C. Maury who have made a detailed study of the spectra of the bright northern stars, also by Miss M. C. Stevens and Miss L. D. Wells, all of whom are women having more than one discovery to their individual credit. The Observatory has a corps of about forty assistants, seventeen of whom are women, twelve of these are engaged more or less on photographic work.

Photographs obtained with the various telescopes now in use at the Harvard Observatory are of various classes. The most important of these are chart plates having exposures of from ten to sixty minutes; spectrum plates having the same exposure and heat plates having several exposures of a few seconds duration.

Women assistants are not engaged during the night in taking photographs, but find their time during the day sufficiently occupied in examining, measuring and discussing them and in the various computations therein involved.

The most important work at present along this line is being done from the chart plates taken with the eight-inch Draper telescope. This consists in the measurement of stars for standards of stellar magnitudes. Measurement of about forty thousand plates are now being made by Miss Eva F. Leland, Miss L. D. Wells and Miss C. S. Stevens and have shown great accuracy in making the identification of stars shown in the photographs with those contained in existing catalogues.

Photographs of stellar spectra are all carefully examined in order to detect new objects of interest such as 3rd, 4th and 5th type stars or those whose spectra consists mainly of bright lines.

Many interesting discoveries have been made from the study of these photographs of stellar spectra. First in importance was the discovery made by Professor Pickering that Ursa Major is a

close binary star the components revolving around each other at a velocity of about 100 miles a second in a period of about fifty-two days. This discovery led to the finding of a second object of this class, namely Aurigæ by Miss A. C. Maury. Micrometric measurements of the lines in the photographic spectra of the bright stars have been made by Miss Florence Cushman. From an examination of the photographs of stellar spectra, thirty-eight stars having spectra of the fifty type have been added to the sixteen previously known, making the number now known forty-four in all.

About six or eight years ago an astronomical bureau was started at Columbia University, New York City, under the direction of Professor J. K. Rees, Miss Flora E. Harpman, a graduate of Carleton College, but then an assistant at the Smith College Observatory, Northampton, Mass., was called there as head computer. It has developed until it is now one of the most trustworthy and accurate calculating and computing means in the country. Miss Harpman is ably assisted by Miss Magill of Swarthmore College, and Miss Tarbox and Miss Davis both of Vassar.

Over thirty years ago Lewis M. Rutherford began in New York City his experiments in astronomical astronomy. He continued his work for over twenty years. His best photographs were taken with a refracting equatorial corrected for chemical rays of light. This telescope was 11¼ inches in aperture and had two object glasses, one for seeing and the other for photographing. He used wet plates entirely. Mr. Rutherford devised and constructed his own machine for measuring the star plates. This was arranged so as to measure the position, angle, and distance of every star on a plate from a known central star. In 1890 Mr. Rutherford gave all his best negatives to Columbia University. When this collection of negatives was turned over to the Observatory it was arranged to have the work of reduction of the measurements of the star plates pushed forward as rapidly as possible. Mr. Harold Jacoby, assistant at the Observatory, undertook the reduction of the Pleiades plates. Rutherford Stuyvesant, son of Mr. Rutherford, although not interested in science himself, gives $1,000 every year to defray the expense of reduction and publication of results of the Rutherford negatives. The women computers have charge of this work.

Notwithstanding the various way in which the preceding sketches reveal woman's application of thought and energy to the cultivation of astronomy, nothing has been of such aid to its

development as the unbounded liberality of some of our American women. The most notable patronesses are Mrs. Henry Draper, of New York City, Miss Catherine Bruce, of New York City, and Miss Alice Bache Gould, of Boston.

Dr. Henry Draper in 1872 was the first to photograph the lines of a stellar spectrum. His investigation, pursued for many years with great skill and ingenuity, was most unfortunately interrupted in 1882 by his death. Early in 1886 Mrs. Draper made a liberal provision for carrying on this investigation at the Harvard Observatory under the direction of Professor E. C. Pickering as a memorial to her husband. She gave several instruments and contributes $10,000 annually for the work of this department. Owing to the extensive field of investigation in this branch of astronomical physics Mrs. Draper has decided to greatly extend the original plan of work, and to have it conducted on a scale suitable to its importance. In this work Dr. Draper's 11-inch photographic lens is used, for which Mrs. Draper has provided a new mounting and Observatory. There are also at Cambridge a 28-inch reflector and its mounting, also a 15-inch mirror, both gifts of Mrs. Draper. In the Observatory there is a central room where the comparison of charts and photographs is carried on. This is known as "The Draper Memorial Room."

The most unbounded liberality so universally bestowed by Miss Catherine Bruce upon every branch of astronomy in all parts of the world will make her name go down in future ages as worthy of unlimited admiration. One can hardly pick up an astronomical publication in these days without finding a mention of some new gift from her to astronomy,—$250 to purchase a small instrument for a zealous astronomer in a far away island of the sea; $25,000 to aid in the removal of a vast Observatory to a better location; $15,000 to pay for printing various valuable astronomical researches; $50,000 to purchase a new photographic telescope. These are but a small portion of her benefactions bestowed with so much wisdom as to make the first gift no less acceptable than the last. Miss Bruce has been called "the Maecenus of Astronomy." Her intelligent generosity knew no limits of race or country. Her kind and thoughtful care lightened many a burden in her own land and helped to finish many a task where patience and other resources were nearly gone. To Professor Max Wolf at Heidelberg she gave $10,000 for a telescope. With this instrument he discovered a new asteroid and named it "Brucia" in honor of Miss Bruce.

Harvard and Columbia seem to have been the institutions

which have gained most through Miss Bruce's liberality. To the former, from time to time, she gave $50,500, and to the latter $14,100. Her donations to astronomy in ten years from June 1889 to Nov. 29, 1899, amounted to $174,275.

Miss Bruce was born January 22, 1816. Her home was in New York City, where she died March 13, 1900. She was a daughter of George Bruce, the famous type founder. She was an accomplished woman, having a knowledge of Latin, Greek, French and Italian. She was for many years an invalid. She has left a gracious memory of good and generous deeds and an impressive example of noble womanhood.

Miss Alice Bache Gould was educated at Bryn Mawr College, Penn. After graduation she went to Cambridge, England, where she took a degree at Girton College. After her return home she became instructor in mathematics first at Carleton College, Northfield, Minn., and afterwards at Chicago University.

She has written a book on some extensions of Euclidean geometry, also a life of Louis Agassiz, which authorities regard as the best that has appeared notwithstanding its small compass. She is a woman of high intellectual caliber, most discriminating taste and judgment, and a lovable character.

On November 17, 1897, she gave the sum of $20,000 to the National Academy of Sciences as trustee, to establish a fund to be known as "The Benjamin Apthorp Gould Fund," in memory of her father. The income was to be used to assist the prosecution of researches in astronomy. The administration of this income in accordance with the terms of the trust and of a letter of instruction from the donor, was placed under the direction of Louis Boss, Seth C. Chandler and Asaph Hall.

"The object of this fund is first to advance the science of astronomy, and secondly to honor the memory of Dr. Gould by ensuring that his power to accomplish scientific work shall not end with his death. In recognition of the fact that during Dr. Gould's life-time his patriotic feeling and ambition to promote the progress of his chosen science were closely associated, it is preferred that the fund should be used primarily for the benefit of investigators in his own country and of his own nationality. But it is further recognized both by the donor and by the directors that sometimes the best possible service to American Science is the maintenance of close communion between the scientific men of Europe and America, and therefore, even while acting in the spirit of the above restriction, it may occasionally be best to apply the money to the aid of a foreign investigator working

abroad."

The wish was also expressed by the donor that in all cases work in the astronomy of precision should be given the preference over work in astrophysics, both because of Dr. Gould's predilection and because of the present existence of generous endowments for astrophysics. "Finally the B. A. Gould Fund is intended for the advancement and not for the diffusion of scientific knowledge. And is to be used to defray the actual expenses of investigation rather than for the personal support of the investigator during the time of his researches without excluding the latter use under the most exceptional circumstances."

(C. F. Report of B. A. Gould Fund).

Whatever women may be capable of, individual cases at least show that she can do much and do it remarkably well when her enthusiasm is thoroughly aroused. In all cases under our notice there has been present to a wonderful extent, devotion, patience, persistence, generosity, to which has been added in some instances, a deep intellectuality. Therefore let us hope that in astronomy, which now offers a large field for woman's work and skill, she may, as has been the case in several other sciences, at least prove herself man's equal.

December 30, 1903.

MAGNE-CRYSTALLIC ACTION AND THE AURORA.

M. A. VEEDER.

FOR POPULAR ASTRONOMY.

Magne-crystallic action plays an important part in determining the location of auroral clouds, arches, streamers, and bands, and their coloration. The ice crystals of the upper atmosphere assume the shape exclusively of hexagonal prisms, and all crystallic bodies of such sort tend to place themselves with their axes parallel, or perpendicular, to lines of magnetic force, according as they are paramagnetic, or diamagnetic, in their behavior. Thus these prisms of ice must assume definite positions in reference to currents of electricity constantly, or fitfully, traversing the atmosphere. In the case of a current following a stratum of air that is homogeneous, as is most apt to occur in a horizontal direction, these prisms, if diamagnetic, will have their axes vertical, no matter what may be the position of others in strata adjoining. Thus there is an arrangement similar in principle to that employed in the prismatic lenses and reflectors in light-

houses, to concentrate the light in particular directions. In the case of crystals floating in the air in cloud-like forms, and behaving somewhat differently, it may be, in strata at different elevations, and differently electrified, there will be interferences and irregularities, and composite effects, but nevertheless so long as the angles of reflection and refraction involved remain the same there will be concentration of effect in certain definite directions from the source of luminosity, just as appears in the case of halos about the Sun and Moon, which are produced in this very way. Hence it is not possible to determine the position in space of the source of auroral light, by simply taking the apparent height of arches and streamers. As in the case of the rainbow every observer sees his own arch, or streamer, and furthermore every auroral arch, like a halo, must be seen at an angle of twenty-two, or forty-six, or even ninety degrees from the direction of the source of the light which originates it. There are chromatic diffraction effects apparent in certain cases also, which afford additional evidence that the features of the aurora under consideration are originated in precisely the same way as the halo. In the case of the aurora the problem is complicated by the cloud-like distribution, more or less widely diffused, of the source of light, it not being such a source of illumination, definitely circumscribed, and of definite size, as are the Sun and Moon in the production of the ordinary halo. Consequently there may be reduplication of arches where an auroral cloud splits into two or more parts, each having its own arch-producing effect at its own proper angle of refraction. Such irregularity in auroral cloud-forms that are specially brilliant, and well defined, may transform the resultant arches into curtains. So an arch is sometimes seen slightly flattened, or of elliptical shape, or very much thickened at some one part. Rarely an arch has been seen forming a complete ellipse not extending below the horizon. More frequently however a portion only of such an ellipse is seen distorted into the form of a curtain. Attendant upon such refraction there is, as in the case of the halo, more or less coloration. It is likely however, that the deep red color of the aurora seen at times is due to the electric currents traversing the more rarefied strata of the upper atmosphere, coloration of this particular type appearing when an electric current is transmitted through a vacuum tube from which the air is nearly exhausted. Superadded to all these forms of luminosity and coloration there is the effect of reflection from the outer surfaces of the ice crystals floating in the air. These crystals having their major axes parallel with each

other, and the surfaces corresponding to their remaining axes at all possible angles with each other; the effect of reflection from the lateral surfaces thus arranged is to transform a spot of light into an elongated streak; thus, originating streamers, especially in the vicinity of arches and auroral clouds, and having the colors of such arches and clouds. Thus in order to determine the position of the source of auroral luminosity in space it is necessary to take into the account the magne-crystallic action of ice particles in the upper atmosphere as determining the distribution of light by refraction and reflection.

The writer has noted instances in which the non-appearance, or very faint appearance of an aurora that was brilliant at the same or even lower latitude a few hundred miles away has been due apparently to absence of the atmospheric conditions on which the formation of high cirrus cloud composed of ice crystals depends. Also certain displacements of auroral phenomena from the magnetic meridian, or the magnetic zenith, may be the effect of refraction or reflection of light alone in the manner that has been described. It is to be noted however that after due allowance has been made for such reflection and refraction there are displacements due to the nature of the electrical forces involved, a temporary magnetic pole being developed by induction from the Sun, thus causing auroral luminosity to originate at points somewhat removed from the permanent magnetic pole of the Earth. In order to understand from the behavior of the aurora the play of the electrical forces involved it is necessary as a preliminary step to clear up the subject of magne-crystallic action, about which so far as the writer is informed not a word has been written in this connection, the theory of the halo, as well as that of the aurora, being incomplete in this regard. That there is such a phenomenon as magne-crystallic action appears in the text books on Physics generally, but its application to the case under consideration has not been made, and it would seem to be a very serious omission.

LYONS, N. Y., Jan. 16th, 1904.

VENUS, 1903.

PERCIVAL LOWELL.

In 1903 I observed Venus from February 18 to July 25. In view of the difficulty of the subject, and of the possibility of psychical illusion in the case, I took special care against self-de-

ception in my scrutiny of the markings presented by the disk. Nothing was set down without a caveat until I had assured myself of the certainty of its non-subjective existence. Two points I examined specifically: one the objective assurance of the psychical perception; the other the space-prolongation of an impression by movement of the eye. With regard to the first point, experiments on the visibility of a wire* show that it is possible by direct consciousness to part the true from the spurious. Although it is possible to see illusory lines, it is also possible to become cognizant of the fact. If one pay attention, an hallucination of the sort may be found to differ from a presentation of fact by the absence of the sense of reality. I am speaking, of course, only of one kind of hallucination, upon which I have myself made experiments. A peculiar consciousness of objectivity accompanies an impression started from without which is wanting in one originated from within. Upon such direct consciousness we rely, indeed, in all our relations of life. With regard to the second kind of illusion, the transference of a perception from one point to another by motion of the eye, experiments have led me to believe in the possibility of its production at times near the limit of vision. Whether the transference is due to continuity of impression, for the eye retains an impression for the twentieth of a second, and might thus conceivably superpose a first image upon a second part of the field, or whether it be an ideo-sympathetic effect, I am not aware, nor is it for our purpose vital to inquire. That it may be produced, and that it may also be precluded by holding the eye still is sufficient. This plan I adopted. It is not so easy as one might imagine; for bent on detection, the eye has a roving drift hard to hold in check.

Of the markings to be made out upon the disk, there are two kinds. The nicks in from the terminator, the collar round the south pole, and the two spots upon it, like beads upon a necklace, belong to the first and most obvious class. Of them I have never entertained the suspicion of a doubt, and they alone are sufficient to show that the planet's rotation is an affair of about 225 days. To the second, and more difficult kind, belong the long shades which starting from the terminator seek the center of the disk. These, both from their faintness and from their suspicious configuration, are more open to question, and demand the most critical attention. It is they that have most to tell us of the planet's present surface conditions.

* Lowell Observatory, Bulletin No. 2.

The observations of 1903 were confirmatory, to the extent of their detection, of both classes and reaffirmed the existence of many of the markings seen before in 1896-7 and 1901. Of the first class, the south polar collar and the two spots, Astoreth and Ashera, which figured in the map of the planet I made in 1897, showed much as they had showed then. The tooth-like shadings denting the terminator at the outer ends of Anchises regio and Hero regio were likewise once more noticeable. So that the markings, in which illusion of the kind suspected was not concerned, asserted thus their objective existence. With regard to the other sort the proof of actuality was two-fold. In the first place, the lines making in from the terminator which constitute the spokes of the above singular configuration, appeared again in the same places they had occupied in 1897 and 1901. This alone is very strong evidence of their reality. In the next place, these markings came out at times with a definiteness to convince the beholder of an objectiveness beyond the possibility of illusion. Instances of this I shall now quote from my notes:

March 22, $13^h\ 55^m$. "Never felt more sure of the reality of the markings (Anchises and Hero, as well as the collar and its two spots)."

April 13, $12^h\ 44^m$. "This marking (Hero) is unmistakable. It came out in a way that could not have been an optical training in from the rim; as it were all together."

The point here is the preclusion of the effect on the retina of prolongation of a nick on the terminator on to the disk by a rapid motion of the eye. Again:

April 13, $13^h\ 08^m$. "These markings (Anchises and Hero) are as sure as markings can be."

April 14, $7^h\ 18^m$. "Tried to keep the eye from running in from the terminator, and in this manner saw the lower marking (Hero)."

April 14, $12^h\ 52^m$. "The lower marking comes when I keep my attention on the center of the disk—(I) try and succeed in not letting the eye strike in from the terminator."

April 24, $13^h\ 00^m$. "The collar south seen with absolute certainty as reality, seeing 7."

April 30, $13^h\ 00^m$. "Seeing 7, collar beautifully seen."

May 18, $13^h\ 02^m$. "South collar again, certainly there. Also dark tooth at north."

May 22, $12^h\ 38^m$ to 49^m. "The markings come out like an etching. No illusion effect whatever."

May 27, $13^h\pm$. "Find on turning to Mars the details of that planet not so sharp as those of Venus were, but Mars is fainter and not so high up."

June 30, $11^h\ 52^m$. "At first glance one sees the notches in below the cusps. There is nothing analogous the case with the Moon to the naked eye. Therefore they are not optical effects."

All the above observations in Greenwich mean time.

A condition affecting the visibility of the markings which I had

noticed in 1896-7 was again apparent: The phase shown by the disk at the time. The nearer the disk is to the full, the easier the markings are to make out. This peculiarity is independent of the altitude at which the planet be observed. So that it is here not question of terrestrial conditions, but of the verticality or obliqueness of illumination of the Venusian surface. The more vertical the Sun the easier it is to see the features of the planet. For this reason apparently certain markings pass from view as they pass from the center of the disk, while others before invisible emerge to sight as they near that point.

In pursuance of this principle it is imperative in the comparison of drawings to consider only those made under like phase. If this be done with the picturings of the planet made by Schiaparelli on December 9, 14 and 21, 1877,* July 5† and July 30‡, 1895, and with that of Fig. 4 of this paper made June 23, 12^h 5^m, G. M. T., 1903, a very striking agreement will be perceived, an agreement so close as to carry instant conviction of a depicting of actuality to an unprejudiced mind. The collar, composed of the markings called Hephaestus regio and Dione regio, on the chart of 1897, is deducible in the drawings of December 9 and 14, 1877, more evident in that of December 21, 1877, and striking in those of July 5 and 30, 1895. The dark opening in it, marked *h* in the drawing of December 21, 1877, and visible again in that of July 30, 1895, which latter sketch Schiaparelli considered the best of all, is the Paris regio of the chart and appears in Fig. 4 lettered as *a*. The other dark indentation toward the limb to the left in the drawing of July 30, 1895, is the *b* of Fig. 4. Of these two dark points upon the limb I took position angles with the micrometer during June and July 1903, which speaks for the visibility of the markings. Indeed the difficulty of the micrometric measures came not so much from the markings as from the uncertainty of tangential determination near the cusp of the dichotomized disk. The position measures were as follows:

Marking *b*.

G. M. T.	No. of Meas.	Mean P. A.	θ¶	Angle from cusp.
June 17, 12^h 11^m—24^m,	3	132°.9	103°.5	29°.4
23, 12 11	1	125 .0‖		
26, 12 12 —22	3	132 .5	106 .6	25 .9
30, 11 58, 12^h 9^m	3	134 .0	107 .9	26 .1
			Mean	27°.1

* Schiaparelli's Papers, 1878.

† Rendiconti del R. Ist. Lomb., Serie II, Vol. XXVIII, 1895.

‡ Acad. Roy. de Belgique Bulletins, Serie 3, Tome XXX, 1895.

¶ The angle which the line joining the cusps, or extremities of the illuminated portion, makes with the meridian.

‖ Taken parallel to line, not tangentially to limb.

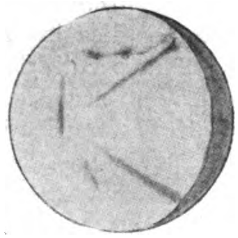


Fig. 1.
March 22, $13^h\ 55^m$, G. M. T., $\lambda = 39°$

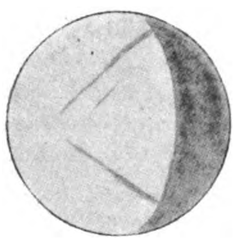


Fig. 2.
April 14, $7^h\ 8^m$, G. M. T., $\lambda = 48°$

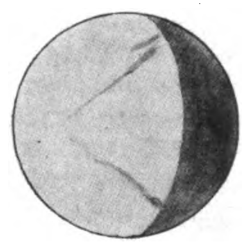


Fig. 3.
April 14, $12^h\ 52^m$, G. M. T., $\lambda = 48°$

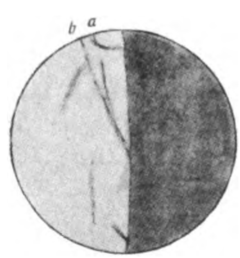


Fig. 4.
June 23, $12^h\ 5^m$, G. M. T., $\lambda = 81°$

Explanation of Drawings.

Fig. 1 shows the collar at the south cusp, the two spots close to it, Astoreth and Ashera, and the long streaks, Anchises regio and Hero regio.

Figs. 2 and 3 show Anchises regio and Hero regio after the lapse of nearly six hours. It will be seen that they are unchanged in place; that is, that the rotation has no perceptible effect in that time.

Fig. 4 shows the aspect of the disk at about the date of dichotomy.

MARKING *a*, TIP OF PARIS REGIO ON LIMB.

G. M. T.			No. of Meas.	Mean P. A.	θ	Angle from cusp.
July	1, 12^h	2^m—10^m,	3	130°.6	108°.2	22°.4
	2, 12	4 —17	4	127 .7	108 .4	19 .3
	8, 11	54	1	130 .8	110 .1	20 .7
	11, 12	30	1	129 .3	110 .8	18 .5
					Mean	20°.2
	18, 11	32 —44	2	132 .4	112 .3	20 .1
	21, 12	38	1	131 .8	112 .9	18 .9
	24, 12	36	1	133 .1	113 .5	19 .6
	25, 12	3 —16	3	131 .4	113 .8	17 .6
					Mean	19°.05
			Mean of all			19 .6

a was measured when the longitude of the center of the disk, λ, was from 79° to 86°; *b*, when it lay between 86° and 102°. At these central longitudes Hero regio is not well seen. On the other hand, when the longitudes of the center lay between 28° and 34°, it was the most evident marking on the disk in 1903, and was conspicuous up to λ = 48°. Similarly in 1901 it was the most salient marking at λ = 23° to 33°. It appears from these instances that a marking is best seen as it passes under the observer's eye.

We may not improperly inquire into the cause of such discriminated showing and when we do so we are led at once to the perception that an atmosphere such as we know Venus to possess should produce just this effect. That the markings are due to cloud forms seems improbable, even in the case of the spoke-like streaks, and quite out of the question with regard to the collar and spots. For their permanency would negative it. The high albedo of the disk is, I am well aware, a difficulty which must be accounted for, but it seems possible to do so by the idea of a bright atmospheric veil as well as by a cloud canopy.

In conclusion it appears necessary, in view of the widespread and persistent misunderstanding of what the markings are, to assert again that they are in no sense canaliform. They bear no resemblance whatever to the "canals" of Mars. They are faint streaks or spots which have nothing about them of the remarkable regularity of the Martian "canals" and oases. They are not of even width, are not dark and sharp cut and do not form a system of interlacing lines. Nor are they ever double. Effects in the drawings which might be so taken differ entirely in look from gemination. Arguments applied to the one set are quite inapplicable to the other. Furthermore, they are of a much higher order of difficulty. Unless the conditions of visibility are such as to

show an observer the "canals" of Mars with ease and certainty it were useless to attempt this much harder planet.—From *Lowell Observatory*, Bulletin No. 6.

January 1, 1904.

METEOR OF SEPTEMBER 15, 1902.

E. L. MOSELEY.

FOR POPULAR ASTRONOMY.

September 15, 1902, a meteor passed northward over Ohio, Ontario, and Michigan, so remarkable in several ways as to deserve more notice than it received from the newspapers at the time.

WHERE SEEN.

As it passed before daybreak few persons were up early enough to see it, and it was a long time before I succeeded in learning of any observers outside of Ohio, acquaintances in other states of whom I enquired replying that they were unable to learn of anyone who saw it. Meteors of less brilliance, observed by my pupils or myself, I had made some effort to trace before, but had not followed them very far; one I concluded had burned out within 25 miles of Sandusky. According to a boy who was up early to carry papers, the meteor of Sept. 15th fell into Sandusky Bay about a quarter of a mile from him and he heard the splash. A man five miles east of the city said it was about 75 feet above the ground when it passed near him. An observer in Cleveland thought it fell into Lake Erie about five miles north of the city. Near Meadville, Pennsylvania, some workmen "saw it fall in the woods" and a Pittsburgh paper undertook to give its weight. By extensive correspondence and the insertion of letters of inquiry in many papers I have learned that it was seen throughout northern Ohio from Defiance to Ashtabula, in southern Ohio in Pike, Perry, Morgan and Washington counties, in western Pennsylvania at Erie, Edinborough and Meadville, in New York at Westfield, in Ontario at many places between Lake Erie and Lake Huron, also at Drayton and Arthur east of Lake Huron, in Michigan at Detroit, Port Huron, Ann Arbor, Lansing, and a number of other places in that part of the state, also in Osceola county about 240 miles west of Arthur, Ontario. So far my efforts to learn of observers in West Virginia or in Michigan north of Saginaw Bay have been unavailing. This, however, does not indicate that the meteor fell into Saginaw Bay, as observers

south of the bay thought, or into the southern part of Lake Huron as observers south of the lake thought. The weather map issued that morning shows a cloudy sky at stations in the northern half of Michigan, also in a part of West Virginia, though over most of this portion of North America the sky was clear.

The Path.

The meteor entered the Earth's atmosphere probably over West Virginia or southwestern Pennsylvania, passed over Mentor, 22 miles east of Cleveland, and over Sarnia, Ontario, near Port Huron, Michigan. Above Mentor its elevation was about 75 or 80 miles, when between London and Detroit about 73 miles. There is no clear evidence of any zig-zag or irregular motion or any bursting of the meteor.

Appearance.

The meteor passed over eastern Ohio and southwestern Ontario at about 5:42 A. M. Washington time. According to most observers it continued visible between ten and thirty seconds. It was egg-shaped or pear-shaped with the large end in front. To many it appeared to have about half the diameter of the full Moon, but was much brighter, giving probably several times as much light as the full Moon. The color was like that of an arc light, white or with a slightly bluish or possibly purplish tinge.

Sounds.

At Waverly in southern Ohio a rumbling sound was heard, but correspondents in southeastern Ohio do not report any sound. At many places in northern Ohio sounds were heard, but not very loud. At Defiance, from which the meteor when nearest was 175 miles distant, four observers interviewed by Dr. C. E. Slocum heard "a hissing noise." An observer near Sandusky heard "a slight hissing noise about as loud as a bee." M. F. Roberts, directly under the meteor at Mentor, heard "a rushing sound" that attracted his wife's attention.

In Michigan E. J. Smith and W. Kearns at Detroit heard "a loud sizzling noise." Near Port Huron an observer reported by C. K. Dodge heard "a great crackling and hissing, supposing at first it was his stove."

In Ontario, Andrew Smale, of Union, compared the noise to "that of an electric car running." The noise was heard by a number of persons in and near London, Ontario. J. B. McMurphy says of the sounds: "first like the swish of a falling tree, then changing to a noise similar to the striking of a parlor match

on some hard surface with not quite sufficient force to ignite it but enough to make it snap. It was something like this—Bir-rup-bir-rup-bir-rup, then changing to a sound like distant cannon. There were three such sounds as those. All those sounds were as if they had been produced from an echo and reproduced several times, each time growing fainter."

The greater intensity of the sound in Canada than in Ohio I suppose was due to the fact that the meteor was then moving through air not so rare as where it first became visible. The sound seems to have been no more noticeable directly under the meteor than many miles either side of its path.

Duration and Extent of the Train.

The train was observed by many who were not up early enough to see the meteor. Geo. D. Berry near Marietta, Ohio, estimated that it remained visible between five and eight minutes, but all observers farther north who kept watch of it give a longer time, quite a number giving "fifteen minutes" or "twenty minutes" or "until daylight." C. K. Dodge, of Port Huron, who is doubtless correct, reports it visible there for more than half an hour. The Pontiac reporter of the Detroit Tribune says "for at least half an hour." J. B. McMurphy, of London, Ontario, assures me that there the train was still visible sometime after sunrise and about an hour and a half after the meteor passed.

As seen from Ypsilanti, Michigan, the train extended so far from south to north that Mrs. F. K. Owen looking out an east window was unable to see either end of it. As seen at Port Huron it extended quite to the horizon a little west of north.

Form and Color of the Train.

At first the train formed an even curve or, as seen from some places, nearly straight line, but in a few minutes it began to be sinuous and gradually became quite zig-zag, as described by a number of observers.

J. B. McMurphy writes from London: "The sparks were very numerous and about the color of ordinary fire sparks. Later they appeared gray like ashes." Others speak of the train as "white," "a light streak," "lead colored streak," "phosphorescent glow," "color of full Moon on a clear night;" Mrs. Owen, Ypsilanti, "a band of shining light, silvery white, brighter toward the north, faded toward the south;" D. C. Johnson, of Marblehead, Ohio: "Sparks appeared to turn to white ashes that stayed until the wind blew them away."

Sandusky, Ohio.

THE OBSERVATION OF VARIABLE STARS.

COL. E. E. MARKWICK, F. R. A. S.

The study of variable stars is becoming more and more important, as the causes to which the light variations are due lie deep in the domain of cosmical physics, and in fact form some of the leading phenomena in the universe of stars. Hence their observation is becoming more and more an important branch of astronomy. Formerly the subject was practically left untouched in the program of official observatories; and even now, although they are watched in a few public observatories, the bulk of the work is being done in private observatories or by amateurs without any observatory at all.

The whole subject is one eminently suited to amateurs, as with comparatively small optical means a great deal of work may be done. A star such as Algol or β Lyræ can *only* be observed with the naked eye, while many such as S Sagittæ can *only* be observed with a binocular. Exception, of course, is made in the case of the photometer, which, however, is such an elaborate instrument as to be unlikely to be in the hands of an amateur. The reason why the stars named can only be so observed is that the comparison stars required to be used lie outside the field of view of the more highly magnifying telescope.

Variable stars, for the purpose of the ordinary, as distinguished from the professional observer may be roughly divided into four principal classes:

1. Algol type. Examples: Algol, U Cephei.
2. Short period. Examples: T Monocerotis, S Sagittæ.
3. Long period. Examples: R Leonis, χ Cygni.
4. Irregular. Examples: R Coronæ, R Scuti.

In the first type the variation in light is, beyond all reasonable doubt, due to the periodical eclipse, by the companion, of the primary star of a double system, in which the latter is bright, while the companion is smaller, and, generally, comparatively obscure. The necessary condition is that the plane of the orbit of the two stars pass through, or nearly through, the observer. With varying conditions of relative size and brightness of the two bodies, eccentricity and inclination of orbit to line of sight, it is obvious that the amount of variation may differ largely in different cases; but the type remains the same, that is to say, the light remains normal for the greater part of the period, the light change being gone through in a comparatively short time. Thus

the "period" of Algol is about $2^d\ 20^h\ 49^m$, while according to Chandler the light oscillations occupy a little over 9^h.

The second type of star has variation generally continuous throughout the period, which latter is usually confined within a few days. The light change is probably due to some orbital cause, but is far more difficult to explain than the first type.

The third type consists of stars whose variation runs into months; in some cases the period is shorter than our year, in others longer. Perhaps, on a very rough average, the period may approximate to our year. The change of light is most probably gradual all through the period, although generally most rapid shortly before or after maximum. There may be practically "'any amount" of variation, from say 5th or 6th magnitude down to absolute invisibility. It is curious that in a powerful telescope some of these stars, when at minimum, present the appearance of a small, dim, nebula. No complete satisfactory theory of the long period stars has yet been given. The light changes appear to originate in the star itself; they may be very distantly analogous to our sun-spot changes, which is about all that can be said.

The fourth type are sufficiently described as "irregular." The light may continue unchanged for weeks or months, and then sudden and well-marked fluctuations in light will occur.

And now as to the observation of variable stars. It is premised in the following remarks that the person for whose edification they are intended has a good general knowledge of astronomy, but has not taken up this particular subject before. And, firstly as to instrumental appliances: much can be done with the naked eye, while a good binocular is all that is required for stars from, say, 4th to 7th magnitude. Below this a telescope is required. A 3-inch refractor with an eyepiece of low power, giving a wide flat field, will enable the observer to follow nearly all the long period variables through the greater, certainly the most interesting, part of their changes. Some of the long period variables at minimum, however, require the very highest optical power, but the amateur perhaps will hardly follow them up so closely as this.

It should not be forgotten that the details of the system of Algol, that is, the relative dimensions of the two globes, their period, the particulars of the orbit, etc., have all been determined from observations made by the naked eye alone, without any instrumental aid. The visual are supported by the spectroscopic observations.

The binocular is of very great use in observations of variable stars, as, firstly, the field of view is sufficiently large to contain in many cases the necessary comparison stars, and, secondly, it is so very portable. Whenever a clear gap occurs in the sky one needs only to pop out into the garden, or even the street, and the instrument can be focussed in a few seconds on the object. Unlike the case of a telescope fixed in an observatory, the observer by shifting his position can often easily "dodge" such intervening objects as trees, buildings, chimneys, or the like. The dark, unilluminated sky of the country is, of course, the best for this work, as it is for all other branches of observational astronomy. In towns, nowadays, observation is very much hampered by the glare from numerous electric lights, as well as by smoke and haze.

It is well to select a few variables to commence with, and concentrate observations on them. One good series of determinations of a variable is worth far more than a large number of scattered sporadic observations of many stars. The following twelve stars are suggested as a commencement, the particulars thereof having been extracted from Chandler's third "Catalogue of Variable Stars," which is a sure guide for the northern, and to a considerable extent, for the southern hemisphere. For the latter, if required, the observer may consult with advantage a "Catalogue of Southern Variables," recently issued by Mr. A. W. Roberts, of South Africa. Both these catalogues have been published in the *Astronomical Journal*, and could probably be obtained from Cambridge, Mass., U. S. A.

WORKING LIST.

Star.	1900.0. R. A.	1900.0. Decl.	Variation. From	Variation. To	Period.	Remarks.
	h m	° ′	mag.	mag.		
U Cephei	0 53.4	+ 81 20	7.1	9.2	$2^d\ 11^h\ 49.6^m$	Algol type.
o (Mira) Ceti	2 14.3	— 3 26	{1.7 5.0	8} 9.5}	331.6^d	Long period.
β Persei, Algol	3 1.7	+ 40 34	2.3	3.5	$2^d\ 20^h\ 48.9^m$	
T Monocerotis	6 19.8	+ 7 8	6.1	7.8	27.01^d	Short period.
R Leonis	9 42.2	+ 11 53	6.0±	9.7±	$312.\ 8^d$	Long period.
R Coronæ	15 44.4	+ 28 28	5.8	13.0	—	Irregular.
Z Herculis	17 53.6	+ 15 9	7.1	8.0	$3^d\ 23^h\ 49.9^m$	Algol type.
R Scuti	18 42.1	— 5 49	{4.7 5.7	6.0} 9.0}	—	Irregular.
β Lyræ	18 46.4	+ 33 15	3.4	4.5	$12^d\ 21^h\ 47.4^m$	{Short period with 2 min.
χ Cygni	19 46.7	+ 32 40	{4.0 6.5	13.5	406.02^d	Long period.
S Sagittæ	19 51.5	+ 16 22	5.6	6.4	8.38^d	Short period.
μ Cephei	21 40.4	+ 58 19	4?	5?	—	Irregular.

N. B.—R Scuti is given as periodic in the Catalogues, but it may perhaps be better described as above.

The above list may be gradually extended as the observer gains experience. Variable stars are constantly being discovered, and the field is of immense extent; although it must be stated there have been many "false alarms" in the past.

If unacquainted with the vicinity of the stars he is going to observe, and his telescope is not provided with "circles," the student should get their position roughly from a star atlas, such as Proctor's. He should prepare a map of the vicinity from the atlas of the "D. M.;" or, as this is perhaps difficult of access to many, he should prepare a little map himself, taking the positions of all the stars contained within a radius of 4° or 5° from the variable, which are to be found in the "Revised Harvard Photometry" (Vol. XLIV., Part I., of *Annals of Harvard College Observatory*). or in the *Photometric Durchmusterung* (Vol. XLV. of the same Annals). For further telescopic work nothing better can be recommended than the "Atlas Stellarum Variabilium" of Father Hagen. The three works named are indispensable.

A uniform system of recording observations should be adopted, as the results can then be obtained with comparative ease. It is convenient to use an observing book of about foolscap size. Enter therein the stars on the working list in order of Right Ascension, taking three folios or so for each star. At the top of page give name and Chandler's number of the variable, its *R.* A. and Decl., with brief particulars of variation, length of period, etc., which can be obtained from Chandler's Catalogue, etc. The maps may well be kept on loose sheets, in a separate portfolio, as they can easily be tilted up at any angle to represent the aspect of an asterism at any time.

Each page of the observing book is to be ruled in vertical columns, to contain the following:

1. Date and observation in G. M. T.
2. State of sky, which may be indicated by the following notation:

 1 = good, first rate.
 2 = not so good; clouds about, or hazy, etc.
 3 = very bad; much hindrance.
 T = twilight.
 M = moon.

3. Instrument used; thus, n. e. = naked eye, Bin. = binocular, T 28 = telescope, power 28, etc.
4. Light estimate.
5. Remarks.
6. Deduced brightness.

We now come to the crux of the whole matter—viz., the completion of column 4. The visual determination of the brightness of a variable star is, as a rule, almost entirely *differential*. That is, it is made by comparing its light with that of other stars in the vicinity, whose "magnitude" (or brightness) is laid down. Suppose we have two suitable comparison stars, *a* and *b*, whose magnitudes as given in the catalogue are 4.2 and 4.9 respectively, and that a variable lies somewhere between them as regards briliancy. Then there are two ways of estimating the brightness of the variable. *First*, by estimating at what fraction of the whole light-interval between *a* and *b*, from either one or the other of the two stars, the variable lies. Suppose it was thought to be at one-quarter the interval from *a* towards *b* (and therefore by implication three-quarters from *b* to *a*). This works out thus:

a.	4.2 mag.	To 4.2 mag. of *a*
b.	4.9 "	Add 0.18, as the var. is fainter than *a*.
Diff.	0.7	Result 4.38 mag., or brightness of the variable.
1 quarter	0.18	

Or we might say:

Diff. as before	0.7	From 4.9 mag. of *b*
3 quarters	0.52	Subtract 0.52, as the var. is brighter than *b*.
		Result 4.38 as before.

A convenient method of recording this particular observation is

a (1) *V* (3) *b*,

which explains itself, *V* indicating the variable, which is placed *after* the brighter star, and *before* the fainter one.

The *second* method is by the use of "steps;" the observer may estimate how many steps or tenths of a magnitude the variable is fainter than one star (say *a*) and brighter than another (say *b*). Supposing the observation to be "2 steps fainter than *a*, and 3 steps brighter than *b*;" then assuming that the observer's "step" corresponds truly to 0.1 of a mag., this works out:

By first determination	4.4 mag.	
By second "	4.6 "	
Mean	4.5 "	resultant brightness of the var.

The second may be in the same form, viz.:

a (2) *V* (3) *b*,

but it should be stated clearly in the record, if the fractional method or the step method is used. In either case look at each star separately with the center of the eye, or eyes, not by averted vision.

It is open to the observer to make more than two determinations of brightness if he wish, and the mean of all may be taken. It is obvious also that there will be instances where the variable is exactly equal in brightness to some one of the comparison stars.

In refined methods, it is sometimes the practice for the observer to determine separately the exact fraction of a magnitude to which his "step" corresponds.

Simple determinations of intrinsic brightness of a star without any comparisons are worth little or nothing.

After all these precise instructions, the observer will probably find at first that he makes discordant observations, and sometimes, if he hesitates too much, he will be unable to say whether one star is brighter or fainter than another. After a little practice, however, as in most other things, the light estimate can be made with very fair precision and rapidity.

There are two classes of error which may affect determinations of brightness. These are (1) "Position error," in virtue of which an observer is liable to estimate too highly that one of two stars which has the smallest altitude. (2) "Possible misidentification of comparison stars." It seems hardly necessary to go into either of these in an elementary article like this.

The column "deduced magnitude" can be completed at leisure from the catalogue magnitude of the comparison stars.

In discussing the observations, it seems indispensable to plot them on square ruled paper, the abscissa being the time, and the ordinate the brightness deduced from the observations and ex pressed in magnitudes. A "smooth" or most probable curve is then drawn among the dots representing the observations. From this, if it is complete through a period, the date of maximum and minimum can be read off by inspection, and the character of the variation noted. Short period and Algol types must be plotted according to "phase," *i. e.*, according to the interval elapsed since the next preceding maximum or minimum.

If two or more observers combine their observations, the correctness of the results is vastly enhanced. Such a method as is sketched out above is in vogue in the Var. Star Section of the British Astronomical Association, and a series of results of very great reliability have been the final outcome of the co-operation of less than a dozen workers.—From *Knowledge Diary and Scientific Handbook* for 1904.

ASTRONOMY IN THE HIGH SCHOOL. III.

MARY E. BYRD.

FOR POPULAR ASTRONOMY.

DIURNAL PATHS OF HEAVENLY BODIES.

Ancient peoples who lived much out of doors had a sense of companionship with the heavenly bodies that we of the present day know little of. Not every advance to the estate of high civilization has been net gain. We have magnificent electric lighting, but we have lost the stars. Sun, Moon, planets and stars have dropped out of modern life almost as completely as if they had been blotted from heaven. To win back a place for them in human interest is not an unworthy ambition. Let us, then, who are teachers of astronomy, set for one of our first lessons, that oldest of all astronomical observations, to follow the Sun's diurnal circle in the heavens.

Turning first to one of the simplest methods, we find little required in the way of equipment except note-books, dark glasses, and an unobstructed view of the sky. Students themselves will be interested in finding places where they can conveniently watch the Sun. Neither time-piece nor almanac is essential. Any time within the hour from half after eleven to half after twelve may be taken as noon by them. At that time they should estimate the Sun's distance from the zenith by comparing it with the whole arc of 90° between zenith and horizon. It is not an easy estimate to make, and as there may be an error of 10°, no greater refinement than 5° need be attempted. That is, if the Sun seems a little more than a third of the way from horizon to zenith, its altitude is to be called 35°, if a little less, 25°. Since, however, direct estimates of noon altitude are invariably too large, it is fair to allow our students to correct their observed values by subtracting 5°. In entering the record in the note-book, it is well to include not only the final altitude, but the steps that lead up to it, and also a short description of the place of observing, so that each one may stand in the same place in the evening and on other days when watching the Sun. The evening observation is far simpler. As the Sun gets low in the west it is only necessary to outline roughly in the note-book, the trees or buildings near which its path is likely to meet the horizon, and then mark, with the symbol of the Sun, the point where the body drops out of sight. Five or six times during the school year at intervals of three weeks or more, the Sun's path should be located in this sim-

ple way by fixing the points of southing and setting, and on one of the dates it is desirable to include two or three intermediate positions.

A fair allotment of time to different kinds of observations does not permit so much attention to be given to other diurnal paths as to that of the Sun, but some notion of the way by which the Moon crosses the sky should be obtained on two or three evenings, one chosen when its path runs high and another when it is comparatively near the horizon. If on the latter date, a large part of the semi-diurnal path is traversed in the afternoon and early evening, the following exercise may be assigned.

1. Locate the Moon four times at intervals of half an hour or more, being careful each time to stand in the same place.

2. Before taking the first observation, sketch a part of the horizon line, beginning with the object just under the Moon and passing some distance to the west.

3. Estimate the altitude of the Moon by comparing its distance above an object on the horizon with the height of the object above the ground. Thus, if this is a church spire (blackboard illustration) and this the position of the Moon, you will place the Moon on a line passing through the top of the spire, and three times the height of the spire from the ground.

4. Mark positions found by dots accompanied by the symbol for the Moon.

If on the night of this observation one of the bright planets is near the Moon, its path may be included with little additional effort. Stars also may be observed in a similar manner, but it is far easier to gain a comprehensive idea of their motion with regard to our horizon by taking account of entire constellations somewhat as follows:

1. Record the positions of three constellations in the east with reference to some prominent object nearly in line with one of them.

2. Locate, in like manner, three constellations in the west.

3. At the end of an hour, record again the position of each constellation, noting the direction and amount of its motion.

Besides definite, prescribed observations of diurnal paths, there should be many times from month to month when Moon, planet or star is watched for a few minutes till it moves away from some fixed reference line, like that connecting two tree tops.

Simple methods like those outlined above permit students to receive directions and report results at regular class exercises, while at the same time carrying on work quite independently at

their individual places of observation. When, however, more critical methods are employed, requiring instrumental aid, it is essential to have one fixed place for observing. Preferably this should be near the recitation room and on the ground. Here most of the work is to be done under the direction of the class-room teacher or laboratory instructor. Estimates give place to measures, times are recorded to the nearest minute and noon-time is restricted to a short interval before and after the instant of the Sun's meridian passage. To meet these more exacting demands, the minimum equipment should include a north and south line, altazimuth, celestial globe, clock, ephemeris, and almanac.

A common almanac gives the time of apparent noon within a minute. A common clock should be trustworthy within a fraction of a minute if regulated by the daily time signals sent everywhere by telegraph. The "American Ephemeris and Nautical Almanac" supplies data for checking the small almanac, as well as data needed for the planets. It is found in experience that the home-made altazimuth used on a fair meridian line gives results that compare very favorably with those obtained from more expensive appliances. The line itself requires, perhaps, more attention than the instrument. When the place chosen for observation is on the ground, this line should be located on a large flag-stone, levelled and set even with the surface of the ground, its foundation being a deep layer of sand so as to dimish the effects of the weather. A gnomon post set up at the south side of the stone, and carefully adjusted, casts at apparent noon a shadow which lies directly north and south on the stone. If, then, the edge of the shadow is marked on four or five days, the mean position of the different lines thus fixed ought to give a meridian line sufficiently accurate for all except time observations. Thus furnished forth with time, meridian line, and an instrument for measuring angles, students can obtain positions in diurnal paths by merely pointing at the body and reading off altitude and azimuth from the graduated circles. Now, as in the work of astronomers, reduction and discussion take an important place. All paths should be plotted on rectangular paper, and critical points, rising, southing, and setting, checked on the celestial globe. The globe is also helpful in supplementing observations, showing as it does the symmetry of diurnal motion on either side of the meridian and illustrating paths of heavenly bodies in widely differing latitudes.

Since many of us who teach astronomy were never trained in

laboratory methods, there is danger of assigning unreasonably laborious or even impossible tasks. The most elementary exercises are not so simple as they seem. They require more time and effort, there is more in them than appears, facts, that stand out very clearly if we conscientiously undertake to follow our own instructions.

Times are long in astronomy. The shortest diurnal paths are seldom traversed in less than nine hours. Beginners, like more experienced observers, must often content themselves with following in the heavens only a small part of the path in which they are interested.

SMITH COLLEGE OBSERVATORY,
NORTHAMPTON, Mass..

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury will be visible as evening star during the latter half of the month. being at greatest elongation, east from the Sun 20° 12′ on the afternoon of Apr. 21. Mercury will be in conjunction with Mars on April 8 but both planets will then be too near the Sun to be seen with the unaided eye.

Venus is morning star, seen near the eastern horizon an hour before sunrise. She is on the farther side of her orbit from us and presents nearly the full phase, but her brilliancy is getting near its minimum, because of her great distance from the Earth. Venus is at aphelion or greatest distance from the Sun April 1. She will come into conjunction with Jupiter on the morning of April 23, at 4 o'clock, C. S. T., the two planets being only 30′ apart in declination at that time.

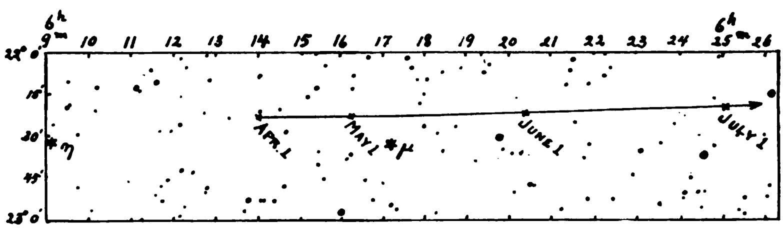
Mars is too close to the Sun to be observed easily, setting less than an hour after the Sun.

Jupiter is morning star, with Venus, now, but is not yet far enough out of the twilight for satisfactory observing.

Saturn may be observed toward the southeast in the morning hours, ir the constellation Capricorn.

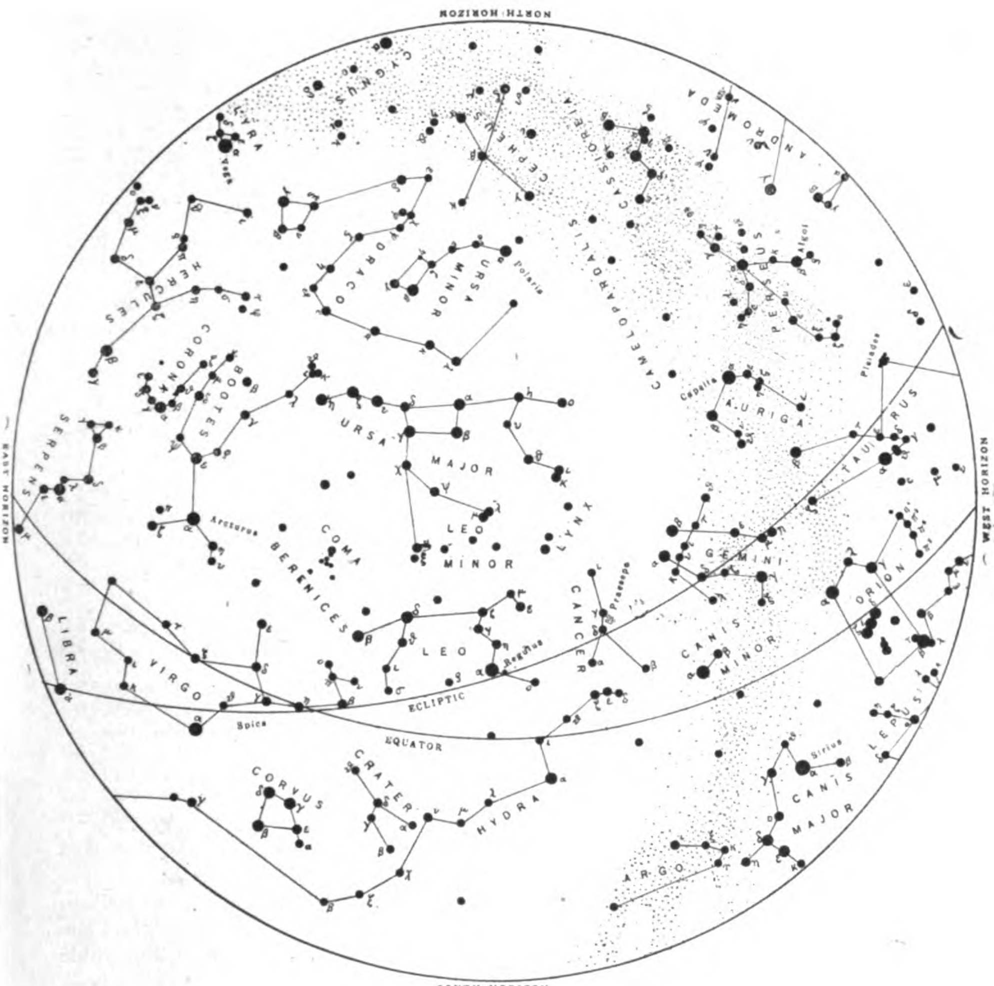
Uranus is at the stationary point of its path, at the west end of its course for the year, between the constellations Sagittarius and Scorpio. It may be observed with the aid of a telescope in the morning hours.

Neptune is the only planet in favorable position for evening observation. It may be found, with the aid of a telescope, in the constellation Gemini, between



APPARENT PATH OF NEPTUNE AMONG THE FAINT STARS NEAR μ GEMINORUM.

the stars η and μ. With the finder of a small telescope get the middle point between these two bright stars, then move the telescope to the sonth about one.



THE CONSTELLATIONS AT 9 P. M. APRIL 1, 1904.

third of the Moon's apparent diameter and sweep slowly toward the east Neptune ought either to be in the field of the larger telescope at first or to enter it immediately. The accompanying diagram may assist the observer. It gives the apparent path of Neptune for the next three months, showing all the faint neighboring stars whose places are given in the Bonn Durchmusterung. The planet will appear brighter than most of the stars shown along its path.

Ephemeris for Physical Observations of the Sun.

1904.	P.	D.	L.	1904.	P.	D.	L.
	Greenwich Mean Noon.				Greenwich Mean Noon.		
	° ′	° ′	° ′		° ′	° ′	° ′
Jan. 1	+ 2 22	−3 8	203 49	July 4	− 1 14	+3 24	282 5
6	− 0 4	3 42	137 58	9	+ 1 2	3 55	215 54
11	2 29	4 14	72 7	14	3 19	4 25	149 44
16	4 53	4 45	6 17	19	5 31	4 53	83 34
21	7 12	5 13	300 27	24	7 41	5 18	17 25
26	9 27	5 38	234 37	29	9 47	5 42	311 17
31	11 36	6 1	166 47	Aug. 3	11 47	6 3	245 9
Feb. 5	13 38	6 21	101 57	8	13 42	6 22	179 2
10	15 33	6 38	37 7	13	15 31	6 38	112 57
15	17 20	6 52	331 17	18	17 13	6 51	46 52
20	18 58	7 3	265 27	23	18 47	7 2	340 48
25	20 28	7 10	199 36	28	20 15	7 9	274 44
Mar. 1	21 48	7 14	133 44	Sept. 2	21 34	7 14	208 40
6	22 59	7 15	67 51	7	22 44	7 15	142 38
11	24 0	7 12	1 57	12	23 45	7 13	76 37
16	24 51	7 6	296 3	17	24 38	7 8	10 38
21	25 31	6 57	230 9	22	25 20	7 0	304 38
26	26 1	6 45	164 14	27	25 53	6 49	238 38
31	26 21	6 30	98 16	Oct. 2	26 16	6 34	172 39
Apr. 5	26 29	6 12	32 16	7	26 27	6 17	106 41
10	26 27	5 51	326 17	12	26 29	5 57	40 44
15	26 14	5 27	260 17	17	26 19	5 34	334 47
20	25 49	5 2	194 15	22	25 57	5 9	268 50
25	25 14	4 34	128 12	27	25 24	4 41	202 54
30	24 27	4 4	62 8	Nov. 1	24 39	4 11	136 58
May 5	23 30	3 33	356 2	6	23 42	3 39	71 2
10	22 22	3 0	289 55	11	22 33	3 6	5 7
15	21 4	2 27	223 48	16	21 12	2 30	299 11
20	19 36	1 52	157 39	21	19 41	1 54	233 16
25	17 58	1 17	91 29	26	17 58	1 16	167 22
30	16 11	0 41	25 19	Dec. 1	16 6	+0 38	101 29
June 4	14 18	−0 4	319 9	6	14 4	0 0	35 36
9	12 18	+0 32	252 59	11	11 56	−0 38	329 43
14	10 11	1 8	186 48	16	9 41	1 16	263 50
19	8 2	1 43	120 37	21	7 19	1 54	197 58
24	5 48	2 18	55 26	26	4 55	2 31	132 7
29	− 3 31	+2 51	348 15	31	+ 2 30	−3 6	66 16

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node to be 74° 25′. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian. (From *The Companion to The Observatory*, 1904).

The Moon.

1904	Phases.	Rises. h m	Sets. h m
		(Central Standard Time at Northfield. Local Time 13m less.)	
April 7	Last Quarter	1 18 A. M.	11 08 A. M.
15	New Moon	5 33 "	6 54 P. M.
22-23	First Quarter	10 50 "	1 33 A. M.
29-30	Full Moon	7 08 P. M.	5 48 "

Occultations Visible at Washington.

Date. 1904.		Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	Angle fm N pt. °	EMERSION. Washington M.T. h m	Angle fm N pt. °	Duration. h m
Apr.	1	κ Virginis	4.3	7 24	54	7 55	345	0 31
	1	2 Libræ	6.3	13 13	146	14 20	259	1 07
	1	B.A.C. 4772	6.6	13 47	110	15 07	292	1 20
	2	o^2 Libræ	6.3	15 02	133	16 16	259	1 14
	8	τ^2 Capricorni	5.3	14 06	79	15 15	268	1 9
	10	B.A.C. 7774	6.2	16 10	77	17 23	252	1 13
	21	λ Geminorum	3.6	10 30	132	11 18	251	0 48
	30	η Libræ	5.5	8 48	78	9 45	318	0 57
	30	θ Libræ	4.3	15 0	169	15 30	213	0 30

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	at	Local M. T. h m	R. A. ° ′	Decl. ° ′	Mag.
1904 MY	Dugan	Heidelberg	Jan. 10 6 51.4	2 3.7	+ 12 21	12.5
MZ	Dugan	"	10 6 51.4	2 17.1	15 8	10.5
NA	Dugan	"	10 10 30.5	4 48.2	21 57	11.3
NB	Dugan	"	10 10 30.5	5 0.5	22 54	11.2
NC	Wolf	"	10 14 3.5	8 1.5	+ 20 11	12.3

Asteroid Hertha (135) Variable.—A telegram has been received at the Harvard College Observatory from Professor Kreutz at Kiel Observatory stating that Palisa finds that the light of the planet Hertha is variable, with a range of half a magnitude, and a short period.

EPHEMERIS.

G. M. T. d	R. A. h m s	Decl. ° ′	Light.
1904 Feb. 21.5	9 36 52	+ 15 29	1.00
25.5	9 33 4	15 44	
29.5	9 29 28	15 58	
" Mar. 4.5	9 26 8	+ 16 11	0.95

Astronomical Bulletin, No. 147.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.
Feb. 20, 1904.

VARIABLE STARS.

New Variable 1.1904 Persei.—Professor W. Ceraski of Moscow announces in *A. N.* 3924, the first new variable star of the year. It was discovered by Mme. L. Ceraski on 10 photographs taken at Moscow, and varies between the 9th and 12th magnitudes. Its position is

1855	R. A. 2^h 18^m $50^s.0$	Decl. + 50° 37′.7
1900	2 21 50 .5	+ 50 50 .0

The period is not yet determined.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with noon. The hours from 12 to 24 are those which occur in the night in the United States. To obtain Eastern Standard time subtract 5 hours; for Central Standard time subtract 6 hours, etc.]

U Cephei.

	d	h
Apr	2	0
	4	12
	7	0
	9	12
	11	23
	14	11
	16	23
	19	11
	21	23
	24	11
	26	22
	29	10

Z Persei

	d	h
Apr.	1	3
	4	4
	7	5
	10	7
	13	8
	16	9
	19	11
	22	12
	25	14
	28	15

Algol.

	d	h
Apr.	1	17
	4	14
	7	11
	10	7
	13	4
	16	1
	18	22
	21	19
	24	15
	27	12
	30	9

R Canis Maj.

	d	h
Apr.	1	10
	2	13
	3	16
	4	20
	5	23
	7	2
	8	5
	9	9
	10	12
	11	15
	12	18
	13	22
	15	1
	16	4
	17	7
	18	11
	19	14

R Canis Maj.

	d	h
Apr.	20	17
	21	21
	23	0
	24	3
	25	6
	26	10
	27	13
	28	16
	29	19
	30	23

RR Puppis

	d	h
Apr.	6	23
	13	9
	19	19
	26	6

V Puppis.

	d	h
Apr.	2	3
	3	14
	5	1
	6	12
	8	0
	9	10
	10	21
	12	8
	13	19
	15	5
	16	16
	18	3
	19	14
	21	1
	22	12
	23	23
	25	10
	26	21
	28	8
	29	19

S Cancri

	d	h
Apr.	3	8
	12	19
	22	7

S Velorum.

	d	h
Apr.	4	18
	10	16
	16	15
	22	13
	28	12

W. Urs. Maj.

Period $4^h\ 0^m.2$

Apr. 1-26 6^h
27-30 7^h

RR Velorum.

	d	h
Apr.	2	16
	4	13
	6	9
	8	6
	10	2
	11	23
	13	19
	15	16
	17	12
	19	9
	21	6
	23	2
	24	22
	26	19
	28	16
	30	12

Z Draconis.

	d	h
Apr.	1	10
	2	19
	4	3
	5	12
	6	20
	8	5
	9	13
	10	22
	12	7
	13	15
	14	24
	16	8
	17	17
	19	1
	20	10
	21	19
	23	3
	24	12
	25	20
	27	5
	28	14
	29	22

δ Librae.

	d	h
Apr.	2	4
	4	12
	6	20
	9	3
	11	11
	13	19
	16	3
	18	11
	20	19
	23	3
	25	10
	27	18
	30	2

U Coronae.

	d	h
Apr.	4	8
	7	19
	11	6
	14	17
	18	4
	21	14
	25	1
	28	12

R Aræ.

	d	h
Apr.	3	2
	7	13
	11	23
	16	9
	20	19
	25	5
	29	16

U Ophiuchi.

	d	h
Apr.	1	11
	2	7
	3	3
	3	23
	4	19
	5	16
	6	12
	7	8
	8	4
	9	0
	9	20
	10	16
	11	12
	12	9
	13	5
	14	1
	14	21
	15	17
	16	13
	17	9
	18	5
	19	2
	19	22
	20	18
	21	14
	22	10
	23	6
	24	2
	24	22
	25	19
	26	15
	27	11
	28	7
	29	3
	29	23
	30	19

Z Herculis.

	d	h
Apr.	1	1
	2	22
	5	1
	6	22
	9	1
	10	22
	13	0
	14	21
	17	0
	18	21
	21	0
	22	21
	25	0
	26	21
	29	0
	30	21

RS Sagittarii.

	d	h
Apr.	2	23
	5	9
	7	19
	10	5
	12	15
	15	1
	17	11
	19	21
	22	7
	24	17
	27	3
	29	13

RX Herculis.

	d	h
Apr.	1	18
	2	15
	3	12
	4	10
	5	7
	6	4
	7	2
	7	23
	8	20
	9	18
	10	15
	11	12
	12	10
	13	7
	14	4
	15	2
	15	23
	16	20
	17	18
	18	15
	19	12
	20	10

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis.

	d	h
Apr.	21	7
	22	4
	23	2
	23	23
	24	21
	25	18
	26	15
	27	13
	28	10
	29	7
	30	5

RV Lyræ.

	d	h
Apr.	1	7
	4	22
	8	12
	12	2
	15	17
	19	7
	22	22
	26	12
	30	2

U Sagittæ.

	d	h
Apr.	1	15
	5	0
	8	9
	11	19
	15	4
	18	13
	21	22
	25	7
	28	16

SY Cygni.

	d	h
Apr.	1	16
	7	16
	13	16
	19	17
	25	17

SW Cygni.

	d	h
Apr.	4	1
	8	15
	13	5
	17	18
	22	8
	26	22

UW Cygni.

	d	h
Apr.	3	1
	6	12
	9	22
	13	9
	16	20
	20	7
	23	18
	27	4
	30	15

W Delphini.

	d	h
Apr.	2	9
	7	4
	12	0
	16	19
	21	14
	26	10

VV Cygni.

	d	h
Apr.	2	10
	3	21
	5	9
	6	20

VV Cygni.

	d	h
Apr.	8	8
	9	19
	11	6
	12	18
	14	5
	15	17
	17	4
	18	16
	20	3
	21	15
	23	2
	24	14
	26	1
	27	12
	29	0
	30	11

VW Cygni.

	d	h
Apr.	5	7
	13	17
	22	3
	30	14

Y Cygni.

	d	h
Apr.	1	18
	3	4
	4	18
	6	4
	7	18
	9	3
	10	18
	12	3
	13	18
	15	3
	16	18
	18	3
	19	18
	21	3
	22	18
	24	3
	25	18
	27	3
	28	18
	30	3

UZ Cygni.

	d	h
Apr.	17	21

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
Apr.	1	14	Apr.	9	15	Apr.	17	16	Apr.	25	17
	2	14		10	15		18	16		26	17
	3	14		11	15		19	17		27	18
	4	15		12	16		20	17		28	18
	5	15		13	16		21	17		29	18
	6	15		14	16		22	17		30	18
	7	15		15	16		23	17			
	8	15		16	16		24	17			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.6$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Apr.	1	3	Apr.	9	0	Apr.	16	20	Apr.	24	16
	2	6		10	3		17	23		25	19
	3	9		11	5		19	2		26	22
	4	12		12	8		20	5		28	1
	5	15		13	11		21	8		29	4
	6	18		14	14		22	11		30	7
	7	21		15	17		23	14			

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
Apr.	1	19	Apr.	9	12	Apr.	18	17	Apr.	26	21
	2	20		10	13		19	18		27	22
	3	21		11	13		20	18		28	22
	4	21		12	14		21	19		29	23
	5	22		13	14		22	19		30	23
	6	22		14	15		23	20			
	7	23		16	16		24	20			
	8	12		17	16		25	21			

Variable Stars of Short Period not of the Algol Type.

	Minimum.			Maximum.				Minimum.			Maximum.		
		d	h		d	h			d	h		d	h
T Vulpeculae	Apr.	1	6	Apr.	2	15	T Vulpeculae	Apr.	14	13	Apr.	15	22
V Velorum		1	8		2	7	ζ Geminorum		14	18		19	18
δ Cephei		2	3		3	12	W Virginis		15	1		23	6
S Crucis		2	3		3	15	R Crucis		16	1		17	10
V Centauri		2	8		3	19	S Crucis		16	4		17	16
T Crucis		2	15		4	16	Y Sagittarii		16	6		18	1
X Sagittarii		2	16		5	13	X Sagittarii		16	17		19	14
U Aquilae		2	21		5	1	U Aquilae		16	22		19	2
SU Cygni		3	8		5	16	T Crucis		17	2		19	3
X Cygni		3	17		9	22	U Vulpeculae		17	8		20	11
S Sagittæ		4	5		7	15	RV Scorpii		17	16		19	2
R Crucis		4	10		5	19	δ Cephei		17	17		19	3
T Velorum		4	12		5	21	κ Pavonis		17	22		21	17
ζ Geminorum		4	14		9	14	T Velorum		18	10		19	19
Y Sagittarii		4	17		6	12	S Triang. Austr.		18	11		20	13
S Normae		4	17		9	3	SU Cygni		18	17		20	1
η Aquilae		5	3		7	12	V Centauri		18	20		20	7
U Vulpeculae		5	5		7	8	V Velorum		18	20		19	19
RV Scorpii		5	13		6	23	T Vulpeculae		19	0		20	9
V Velorum		5	17		6	16	S Muscae		19	4		22	15
T Vulpeculae		5	17		7	2	η Aquilae		19	11		21	20
S. Triang. Austr.		5	19		7	21	β Lyrae		20	0		23	2
W Geminorum		6	11		9	2	X Cygni		20	2		26	7
R Crucis		6	19		8	7	V Carinae		20	7		22	11
V Carinae		6	21		9	1	U Sagittarii		20	10		23	9
U Sagittarii		6	22		9	21	S Crucis		20	21		22	9
δ Cephei		7	0		8	9	S Sagittae		21	0		24	10
β Lyræ		7	2		10	4	W Sagittarii		21	16		24	16
W Sagittarii		7	11		10	11	R Crucis		21	21		23	6
SU Cygni		7	4		8	12	W Geminorum		21	23		24	14
V Centauri		7	20		9	7	Y Sagittarii		22	0		23	19
κ Pavonis		8	20		12	15	δ Cephei		23	2		24	11
T Velorum		9	3		10	12	T Velorum		23	2		24	11
S Muscae		9	12		12	23	V Velorum		23	5		24	4
X Sagittarii		9	16		12	13	X Sagittarii		23	17		27	14
Y Ophiuchi		9	16		15	21	T Vulpeculae		23	10		24	19
U Aquilae		9	21		12	1	RV Scorpii		23	18		25	4
V Velorum		10	2		11	1	T Monocerotis		23	20		31	18
T Vulpeculae		10	3		11	12	T Crucis		23	21		25	22
R Crucis		10	6		11	15	U Aquilae		23	22		26	2
T Crucis		10	9		12	10	S Normae		24	5		28	15
Y Sagittarii		10	11		12	6	V Centauri		24	8		25	19
TX Cygni		10	18		15	21	S Triang. Austr.		24	18		26	20
SU Cygni		11	0		12	8	ζ Geminorum		24	21		29	21
S Crucis		11	12		13	0	U Vulpeculae		25	7		27	10
RV Scorpii		11	15		13	1	TX Cygni		25	12		30	15
S Trianguli Austr.		12	3		14	17	S Crucis		25	13		27	1
η Aquilae		12	7		14	16	SU Cygni		26	9		27	18
δ Cephei		12	9		13	18	β Lyrae		26	11		29	18
S Sagittae		12	14		16	0	η Aquilae		26	15		29	0
U Vulpeculae		13	4		15	7	Y Ophiuchi		26	19		33	0
V Centauri		13	8		14	19	V Carinae		26	23		29	3
β Lyrae		13	13		16	20	κ Pavonis		27	0		30	19
V Carinae		13	14		15	18	U Sagittarii		27	4		30	3
U Sagittarii		13	16		16	15	V Velorum		27	14		28	13
T Velorum		13	19		15	4	T Velorum		27	17		29	2
SU Cygni		13	20		15	5	R Crucis		27	17		29	2
W Sagittarii		14	2		17	2	Y Sagittarii		27	19		29	14
W Geminorum		14	5		16	20	T Vulpeculae		27	21		29	6
V Velorum		14	11		15	10	δ Cephei		28	11		29	20
S Normae		14	11		18	21	S Muscae		28	20		32	7

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
W Sagittarii	Apr. 29	6	Apr. 32	6	V Centauri	Apr. 29	20	Apr. 31	7
S Sagittae	29	9	32	19	SU Cygni	30	5	31	13
W Geminorum	29	17	32	8	T Crucis	30	14	33	1
RV Scorpii	29	19	31	5					

Approximate Magnitudes of Variable Stars Feb. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	11*i*	R Camel.	14	25.1	+84	17	12*d*
T Cassiop.	0	17.8	+55	14	8*i*	R Bootis	14	32.8	+27	10	10*i*
R Androm.	0	18.8	+38	1	6*i*	S Librae	15	15.6	−20	2	11*d*
S Ceti	0	19.0	−9	53	*f*	S Serpentis	15	17.0	+14	40	*i*
W Cassiop.	0	49.0	+58	1	*u*	S Coronae	15	17.3	+31	44	8*i*
S "	1	12.3	+72	5	12*d*	S Urs. Min.	15	33.4	+78	58	8
R Piscium	1	25.5	+2	22	13*d*	R Coronae	15	44.4	+28	28	6
R Trianguli	1	31.0	+33	50	10*d*	V "	15	45.9	+39	52	*u*
U Persei	1	52.9	+54	20	10*d*	R Serpentis	15	46.1	+15	26	*f*
R Arietis	2	10.4	+24	36	11*d*	R Herculis	16	1.7	+18	38	11*d*
o Ceti	2	14.3	−3	26	4*i*	R Scorpii	16	11.7	−22	42	*s*
S Persei	2	15.7	+58	8	10*d*	S "	16	11.7	−22	39	*s*
R Ceti	2	20.9	−0	38	12	U Herculis	16	21.4	+19	7	8*i*
U "	2	28.9	−13	35	13*f*	R Ursae Min.	16	31.3	+72	28	*u*
R Persei	3	23.7	+35	20	*u*	W Herculis	16	31.7	+37	32	8
R Tauri	4	22.8	+9	56	8	R Draconis	16	32.4	+66	58	10*i*
S "	4	23.7	+9	44	11*i*	S Herculis	16	47.4	+15	7	10*d*
R Aurigæ	5	9.2	+53	28	9*i*	R Ophiuchi	17	2.0	−15	58	*i*
U Orionis	5	49.9	+20	10	10*i*	T Herculis	18	5.3	+31	0	*f*
R Lyncis	6	53.0	+55	28	12*d*	R Scuti	18	42.2	−5	49	*s*
R Gemin.	7	1.3	+22	52	12*d*	R Aquilae	19	1.6	+8	5	*s*
S Canis Min.	7	27.3	+8	32	8*i*	R Sagittarii	19	10.8	−19	29	*s*
R Cancri	8	11.0	+12	2	10*d*	S "	19	13.6	−19	12	*s*
V "	8	16.0	+17	36	9*i*	R Cygni	19	34.1	+49	58	11*d*
S Hydrae	8	48.4	+3	27	8*i*	RT "	19	40.8	+48	32	*f*
T "	8	50.8	−8	46	8*i*	X "	19	46.7	+32	40	9*d*
R Leo. Min.	9	39.6	+34	58	10*d*	S Cygni	20	3.4	+57	42	*f*
R Leonis	9	42.2	+11	54	10*d*	RS "	20	9.8	+38	28	8*d*
R Urs. Maj.	10	37.6	+69	18	13*d*	R Delphini	20	10.1	+8	47	*s*
R Comae	11	59.1	+19	20	*f*	U Cygni	20	16.5	+47	35	8*i*
T Virginis	12	9.5	−5	29	9*i*	V "	20	38.1	+47	47	11*i*
R Corvi	12	14.4	−18	42	7*i*	T Aquarii	20	44.7	−5	31	*s*
Y Virginis	12	28.7	−3	52	10*i*	R Vulpec.	20	59.9	+23	26	*s*
T Urs. Maj.	12	31.8	+60	2	13*d*	T Cephei	21	8.2	+68	5	6*i*
R Virginis	12	33.4	+7	32	7*i*	S "	21	36.5	+78	10	8*d*
S Urs. Maj.	12	39.6	+61	38	12*d*	S Lacertae	22	24.6	+39	48	13*d*
U Virginis	12	46.0	+6	6	11*d*	R "	22	38.8	+41	51	12*f*
V "	13	22.6	−2	39	10*d*	S Aquarii	22	51.8	−20	53	*s*
R Hydrae	13	24.2	−22	46	6*i*	R Pegasi	23	1.6	+10	0	12*d*
S Virginis	13	27.8	−6	41	12*d*	S "	23	15.5	+8	22	8
R Can. Ven.	13	44.6	+40	2	11*i*	R Aquarii	23	38.6	−15	50	6
S Bootis	14	19.5	+54	16	11*d*	R Cassiop.	23	53.3	+50	50	6*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, Vassar College and Harvard Observatories, and by Signor de Moraes Pereira, St. Michaels, Azores.

New Variable 2.1904 Tauri.—This is announced in *A. N.* 3925 by Professor Millosevich of Rome. It is not found in the BD. but is No. 1625 in the *Berlin A. G. Catalogue*, where its position for 1875 is given as

R. A. 4^h 56^m $39^s.51$, Decl. $+ 23°$ $28'$ $7''.5$

In the catalogue the magnitude is given as 9.3 but Professor Millosevich finds it on Jan. 17, 1904 to be 10.3, so that its variability is apparent.

New Variable 3.1904 Cancri.—Professor Wolf of Heidelberg announces in *A. N.* 3925, that a star standing between the three BD. stars $+ 20°$.1992, 1994 and 1997 was of the 12 mag. Jan. 10 and of the 14 mag. Jan. 11, 1904. Its position for 1855 is

R. A. 7^h $56^m.0$, Decl. $+ 20°$ $32'$.

Variable Star 63.1903 Lyræ.—Dr. Hartwig gives the following position of this star in *A. N.* 3921

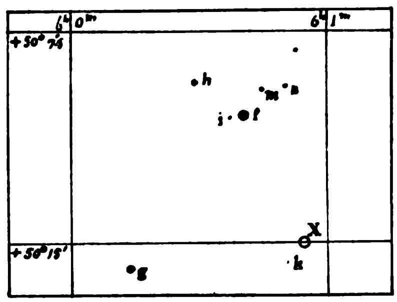
	α			δ		
1855	19^h	9^m	$7^s.51$	$+ 46°$	$43'$	$59''.0$
1900	19	10	24 .12	+ 46	48	36 .3

New Variables 64-85.1903 Aquila.—These are all in the region about γ Aquilæ and were found with the aid of the Stereo-Comparator, upon photographs taken with the Bruce cameras at Heidelberg, July 19.1901 and Sept. 24.1903. The following are their positions for 1900, and the photographic magnitudes on the two dates:

	R. A.			Decl.			Magnitude	
	h	m	s	°	′	″	July 19.1901.	Sept. 24.1903.
64.1903	19	27	48.8	+ 10	18	39	11.5	15
65 "		30	25.8	7	2	14	14	12.5
66 "		33	11.2	12	33	45	< 14	13
67 "		34	2.8	12	2	22	11	14.5
68 "		34	20.2	11	43	5	< 14	13
RV		35	56.7	9	41	57	13	10.5
69 "		36	21.6	7	11	3	14	11.5
70 "		38	6.2	13	20	7	12.0	14.5
71 "		40	21.5	8	12	12	11.0	< 15
72 "		41	47.0	10	32	24	< 15	13.5
73 "		41	56.0	10	13	6	< 15	14
74 "		42	22.6	7	23	4	13.5	11.5
75 "		42	30.2	12	14	19	11.5	< 15
76 "		42	49.4	9	41	57	< 15	12.0
77 "		43	39.8	11	16	33	10.0	12.0
78 "		44	34.8	12	7	7	11.0	13
79 "		46	0.2	12	33	58	14	11.5
80 "		46	15.3	12	58	0	11	< 14
81 "		48	42.4	9	6	37	12	14
82 "		48	59.4	10	44	5	12	13
83 "		49	6.3	9	24	1	11	13
84 "		49	24.8	7	21	1	12.5	11.5
85 "	19	49	32.7	+ 7	44	40	13	< 14

The variable RT Aquilæ (R. A. = 19^h 43^m 17^s, Decl. = $+ 11°$ $29'$, 1900.0) was not visible upon these plates. It seems remarkable that so many variables should be found within so small an area of the sky.

The Light Change of X Aurigæ.—In *A. N.* 3925 Dr. K. Graff of the Hamburg Observatory gives the results of a determination of the light-curve of this variable, which was discovered by Anderson in 1900 and was first designated

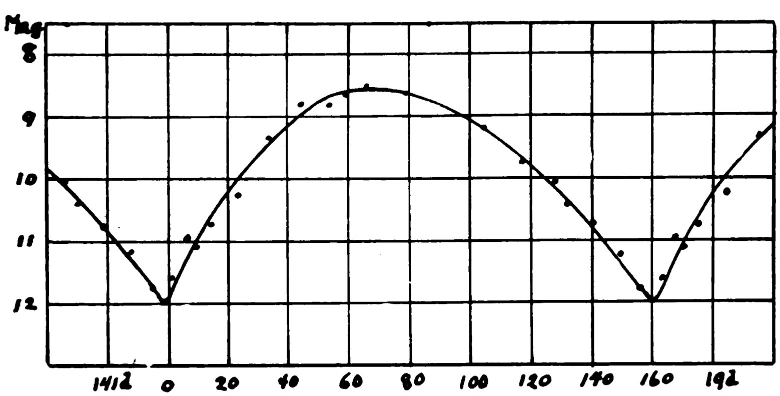


COMPARISON STARS NEAR X AURIGÆ.

as 8.1900 Aurigæ. The observations employed extend from Feb. 26, 1902 to Sept. 19, 1903. He finds the period to be 161 days, the minimum being found by the elements

$$\text{Min.} = 1902 \text{ Oct. } 6 \quad + 161 \text{ E}$$
$$= \text{J. D. } 2416029 + 161 \text{ E}$$

The form of the light curve is shown in the accompanying diagram.



THE LIGHT CURVE OF X AURIGÆ.

Dr. Graff gives the following list of ten comparison stars with their approximate positions for 1855:

		R. A. h	m	s	Decl. °	′	Mag.
a	BD. + 49°1464	6	1	6	+ 49	58.2	8.65
b	BD. + 50°1275	5	58	41	50	10.5	8.45
c	BD. + 50°1281	6	1	21	50	37.9	8.70
f		6	0	39	50	10.8	9.80
g		6	0	14	50	16.0	10.25
h		6	0	29	50	9.3	10.50
i		6	0	37	50	10.9	11.2
k		6	0	52	50	16.3	12.4
m		6	0	47	50	9.4	11.1
n		6	0	50	+ 50	9.3	11.0

GENERAL NOTES.

Our readers will surely be interested in Dr. Wilson's article concerning Eros and the solar parallax which is the leader for this issue. We asked him to give some of the mathematics used in the preliminary reduction, that other practical astronomers might readily see the methods employed. This part of the work is the more important to such, because of the difference of opinion and practice, as to the most desirable method to be used in the reduction of the measures of the photographic plates containing the planet and the comparison stars.

Popular readers who are unable to follow the mathematics will readily get the purpose of the article and understand the results.

Knowledge and Illustrated Scientific News is the new title to one of our valued exchanges that has formerly been under the title of *Knowledge* only. The number for February is an excellent one and well sustains the new title.

Astronomical Photography at Yerkes Observatory.—G. W. Ritchey of Yerkes Observatory has surprised his astronomical friends by the fine photographic work he has been doing recently by the aid of the great 40-inch refractor, and the two-foot reflector. Some of the reproductions of photographs of prominent features of the Moon are themselves little less than perfect. *Mare Sereneitatis Mare Tranquilitatis* and *Mare Nubium* are examples. If the reproduction from the original negatives, by a screen of 200 probably, produces so fine and natural effect, the negatives themselves must be better.

Yerkes Observatory may well be proud of such photographic work, for we doubt if it is excelled anywhere.

Professor George E. Hale is to receive the Medal of the Royal Astronomical Society. The time set for the presentation of the medal was February 12. On account of the remarkable results obtained in solar photography Professor Hale merits this timely recognition from so worthy a source. He is now at Mount Wilson, California, carrying on some investigations pertaining to his own special line of work.

Mars Observed by Denning in 1903.—The *Astronomische Nachrichten*, No. 3926, contains an article by W. F. Denning, giving an interesting description of Mars as observed by himself during 1903. The six drawings that accompany the article give definite ideas of what this careful observer saw at the last opposition.

Phillips' Observations of Mars, 1903.—In *Monthly Notices* for November, 1903, page 39 appears an article by the Rev. T. E. R. Phillips on the Observations of Mars during last year. The article is accompanied by a fine plate showing the markings seen by him at Croydon about the time of the opposition of Mars for 1903. The instrument used was a 9¼-inch silvered-glass reflector, the mirror by With, with powers between 217 and 450. The observations were taken between the middle of February and the end of May on sixty-six occasions. During this time nearly one hundred different markings were under observation, and careful notes and drawings of the same were made and appear in this article. The author's brief summary of all this work is given below in his own words:

"To sum up the results of my observations, a careful and systematic scrutiny of the planet during the past four oppositions has revealed to me the following facts:

(1). Changes partly due to seasonal influences and the appearance of clouds and mists, partly real, unquestionably occur from time to time in the details of the surface configuration.

(2). The main results of Professor Schiaparelli's work are imperishable and beyond question. During recent years some observers have given to the so-called "canals" a hardness and an artificiality which they do not possess, with the result that discredit has been brought on the whole canal system. No doubt the time has come when a distinction must be made between what is real on Mars and what is subjective or illusory, but of the substantial accuracy and truthfulness, (as a basis on which to work) of the planet's configuration as charted by the Italian in 1877, and subsequent years, there is in my mind no doubt.

(3). Contrast, as has been so ably pointed out by M. E. M. Antoniadi, is doubtless accountable for very many of the extraordinary appearances observed on the planet. Not a few of the canals are now seen to be intensified edges of faint tones in accordance with the late Mr. Green's suggestion, while M. Antoniadi's explanation of the gemination as due to some effect of contrast appears both simple and satisfactory.

The Naval Observatory Astronomical Club.—On November 14, 1902, the members of the staff of the U. S. Naval Observatory met to consider some organization through which the current literature of astronomy and related sciences should be presented to its members by reviews or criticisms. This meeting was in response to a call by some of the members of the staff, principally, Assistant Astronomer Theo. I. King and Professor F. B. Littell, through whose efforts the organization known as "The Observatory Club" was effected.

A minimum of organization was secured in having only a "draft" presenting the objects of the Club, and for executive a "Committee of Arrangements," consisting of three members. The first committee, appointed November 14, 1902, the day of organization, consisted of Assistant Astronomer Theo. I. King, Professor F. B. Littell, and E. I. Yowell. Besides the reviews, original papers, and problems in Observatory work were presented at the weekly meetings.

On September 26, 1903, the Superintendent of the Observatory, Rear-Admiral C. M. Chester, U. S. N., recognizing the manifest advantage to all concerned, suggested a re-organization of the Club with an extension of organization and scope of work, and also with the specific inclusion of the staff of the Nautical Almanac Department in such work.

A formal constitution, adopted October 23, 1903, puts "The Naval Observatory Astronomical Club" on a basis with existing scientific associations, and gives as its objects:

"(*a*). The review of appropriate periodical literature, books, and publications of astronomical institutions.

"(*b*). The production and presentation of original papers.

"(*c*). The indexing of the literature of astronomy and related sciences."

The present officers are: Theo. I. King, President; H. B. Hedrick, Vice-President; H. R. Morgan, General Secretary; and W. D. Horigan, Index Secretary.

The advantages of such an organization in a scientific institution having the personnel and scope of work of the Naval Observatory is patent; and the con-

tinued interest of its members insures such advantages. It has been the good fortune of the Club to have eminent astronomers from other observatories take part in its weekly meetings and explain work done elsewhere.

Sun-spot Observations 1902-1903.

Month.	No. of Obs.	N. of Equator. No. Gr'ps.	N. of Equator. Av. Lat.	S. of Equator. No. Gr'ps.	S. of Equator. Av. Lat.	Av. No. at Each Obs.	New Gr'ps.
1902.			°		°		
Jan.	14	0	......	1	— 10.3	0.29	1
Feb.	9	0	......	0	......	0.00	0
March	10	1	+ 22	0	......	0.50	1
April	6	0	......	0	......	0.00	0
May	8	1	+ 24	0	......	0.25	1
Sept.	4	1	+ 18	1	— 26	1.25	2
Oct.	21	3	+ 15.8	3	— 21.3	1.05	4
Nov.	13	2	+ 13.3	0	......	0.31	2
Dec.	8	1	+ 20	0	......	0.25	0
Total	93	9		5			11

Average number visible at each observation.......................0.47
Average latitude of spots N. of equator..............................+ 17°.8
Average latitude of spots S. of equator..............................— 20°.0

Month.	No. of Obs.	N. of Equator. No. Gr'ps.	N. of Equator. Av. Lat.	S. of Equator. No. Gr'ps.	S. of Equator. Av. Lat.	Av. No. at Each Obs.	New Gr'ps.
1903.			°		°		
Jan.	13	0	......	2	— 19	0.31	2
Feb.	15	2	+ 21.3	3	— 23.1	0.80	5
March	14	3	+ 21.4	2	— 20	1.00	4
April	12	4	+ 17.1	2	— 16	2.00	5
May	17	5	+ 14.7	3	— 27.8	1.23	6
June	9	2	+ 16.2	0	......	0.44	2
Sept.	10	1	+ 9.0	0	......	0.20	1
Oct.	17	3	+ 10.9	4	— 22.4	1.71	6
Nov.	18	4	+ 17.5	6	— 23.3	2.17	8
Dec.	13	4	+ 16.0	5	— 22.9	2.92	7
Total	138	28		27			46

Average number visible at each observation.......................1.44
Average latitude of spots N. of equator..............................+ 16°.3
Average latitude of spots S. of equator..............................— 22°.5

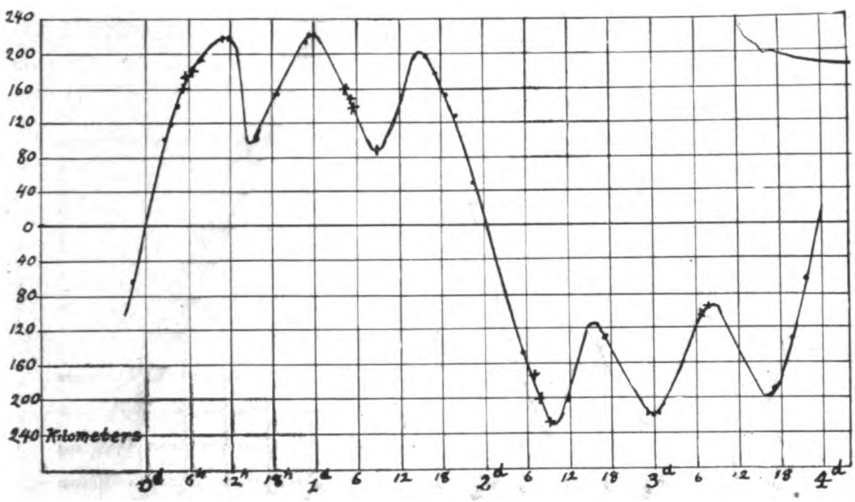
Observations were made by projecting an image of the Sun upon a screen attached to an 8-inch equatorial telescope. Latitudes were obtained with the aid of Thomson's discs.

ANNE SEWELL YOUNG.

MOUNT HOLYOKE COLLEGE.

We notice that Professor F. W. Hanawalt who has been connected for some years with the Wesleyan University at Mount Pleasant, Iowa, has recently left that place for similar work in Albion College, Albion, Michigan.

The Radial Velocity of β Aurigæ.—In *A. N.* 3916 Mr. G. A. Tikhoff of Poulkova, Russia, gives the results of a determination of the radial velocity of β Aurigæ from 41 spectograms obtained at the Observatory of Poulkova by M. Belopolsky in 1902-03. The accompanying diagram shows the curve of the radial velocity of the components of the star, and seems to indicate that the system consists of more than two bodies. The period of the principal components



RADIAL VELOCITY CURVE OF β AURIGÆ.

is found to be 3 days 23 hours and 30.4 seconds. Mr. Tikhoff states that on some of the best spectrograms the line Hγ, which is single at the time of *o* velocity, becomes quadruple at the time of maximum velocity. For example on Jan. 21, 1903 the wave lengths of the four components of the Hγ line, corrected for the movement of the Earth were:

(1)	433.866 very sharp	(3)	434.191 very sharp
(2)	433.933 quite sharp	(4)	434.253 sharp

With these wave-lengths the velocities become

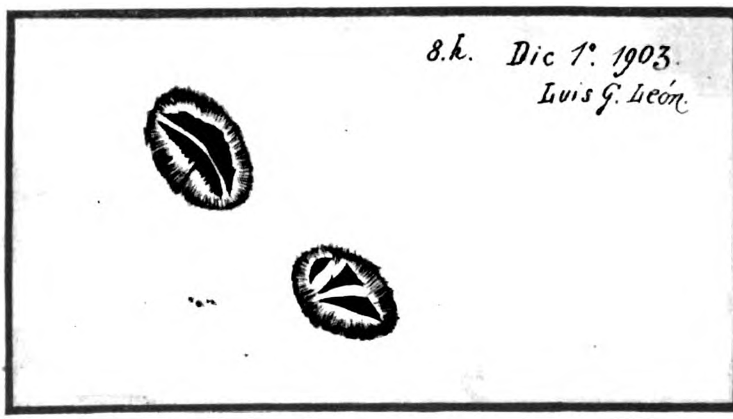
1—2	46 kilometers
3—4	43 "
1—3	224 "
2—4	221 "

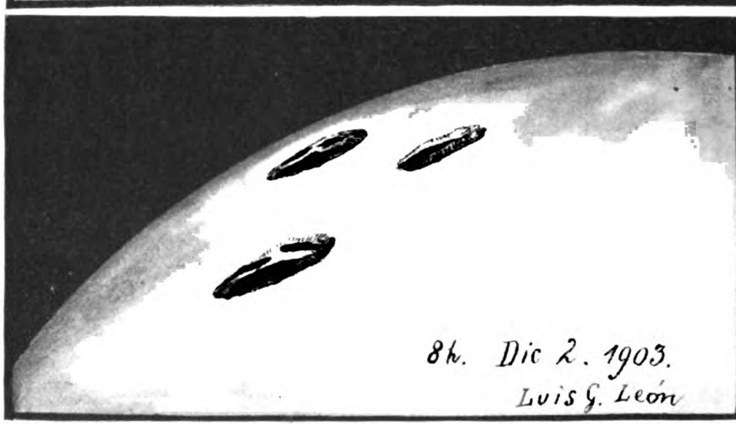
The mean of the wavelengths given above is 434.061, which accords quite exactly with the value 434.059 which was determined on Jan. 24 and Feb. 3. 1903 when the line was single.

The velocity of the whole system, deduced from the Magnesium lines 448.1 and 435.2, is about — 16 kilometers per second. We thus have possibly a system of four bodies, moving as a whole toward us at the rate of about 10 miles per second, while the components form two pairs revolving about each other in 3^{d} $23^{h}.5$, each pair also revolving about its own center of gravity in something like 19 hours.

Sunspots in December, 1903.—The solar activity has continued during the month of December last. Spots and faculæ have been remarkable, especially the latter. On the first day of the month a new spot made its appearance on the eastern limb, and on the 2nd two new spots were visible in the same region. These spots were surrounded by large and brilliant faculæ. The spot which appeared on the 27th of November had the shape of a heart.

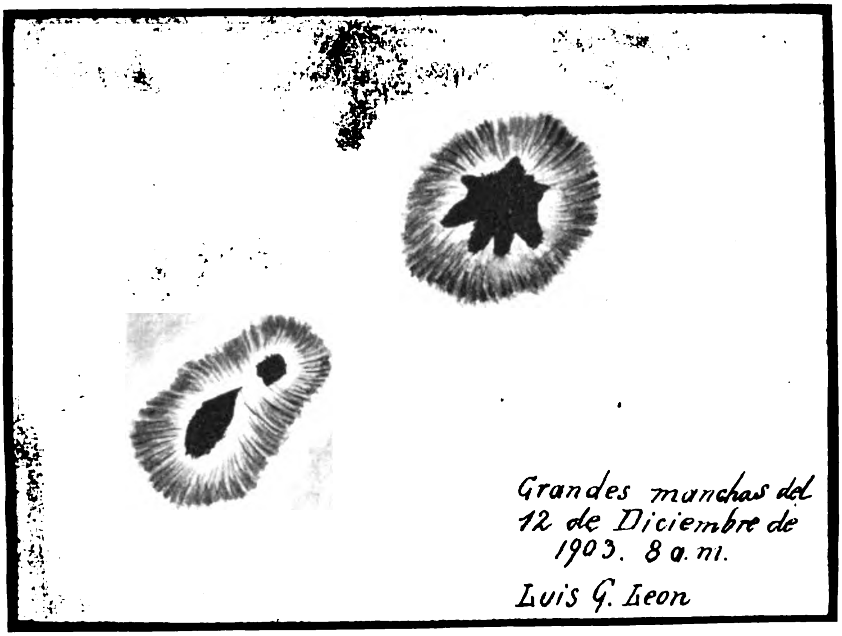
The aspect of the Sun on his eastern edge was very beautiful the 3rd of December. There was a conspicuous group of 15 spots. On the afternoon of the 6th a new spot came on the N. E. limb and still another new one was visible on the 7th. On this same day there was a group whose shape reminded one of that

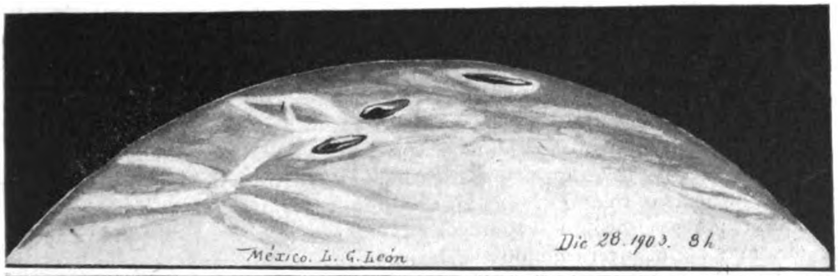




of the constellation of Taurus. I believe that this group is the same famous one of the 31st of October which caused such great magnetic disturbances. On the 9th I saw a great zone of faculæ at the N. E. region of the Sun. What a tremendous activity, what a constant motion, what an immense quantity of liquid and gaseous matter combining there and sending to us waves of heat, light, electricity and magnetism! * * *

On the 10th a new spot was seen coming on the S. E. edge. On the 12th day of the month, we could admire two large spots, of peculiar shape. One gives the


Grandes manchas del
12 de Diciembre de
1903. 8 a. m.
Luis G. Leon


México. L. G. León
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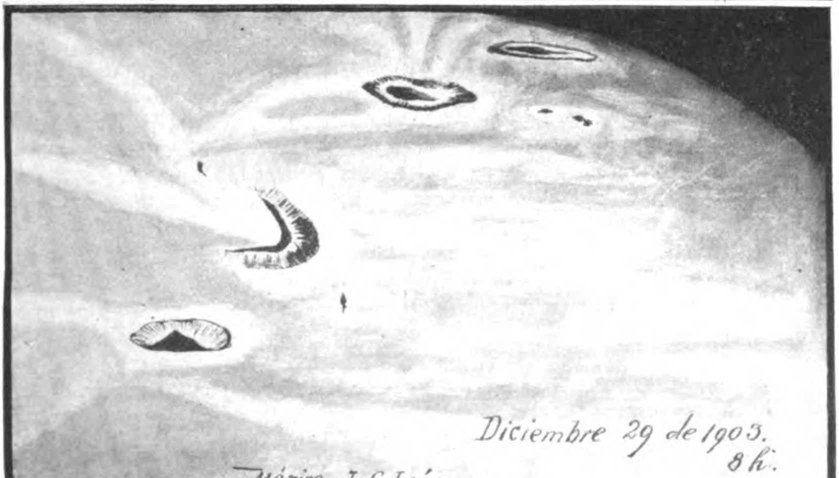
Diciembre 29 de 1903.
8 h.
México, L. G. León.

idea of a black glove and the other of an exclamation point. On the 15th was a new spot at the N. E. This spot presented on the 18th the form of an insect with only three legs, and the 19th separated in two parts, as my drawing shows. On the 22nd the eastern part of the spot divided in two.

Something very curious happened on the Sun the 20th. A group appeared, but not on the eastern edge as is usual; but near the western edge. It was a sudden eruption, and I dare to say that this perturbation was, very likely, due to the attraction of Mars and Saturn which were in conjunction exactly on the same day.

On the 24th began on the Sun a period of rest. On the 26th not a single spot was visible; but a day afterwards 4 spots came at the N. E. with splendid faculæ. New spots on the 28th and the 29th on the eastern limb were seen.

Fifteen new spots made their appearance on the Sun during the month of December, 1903, and brilliant faculæ accompanied them.

I take pleasure in suggesting to the observers of the Sun that they make their drawings on gray paper with lead pencil, representing the faculæ with white pencil. PROF. LUIS G. LEON.

MEXICO CITY, January 1st, 1904.

Auroral Arch, Aug. 21, 1903.—Having read with interest the various accounts in POPULAR ASTRONOMY of the Aurora Boreallis seen over such a large area on the night of August 21, I should like to say that I saw the same phenomenon on the same evening at Duxbury, Mass., a town about 37 miles south of Boston. The description given by the Rev. Mr. Campbell agrees almost exactly with what I saw. The arch I saw was not quite so near the zenith as that seen by Mr. Campbell. In this connection it is interesting to note that the arch seen by Mr. Blatchley at Wayne, Pa., was very far down on the horizon. The highest part of the base of the columns was just below Theta Ursa Majoris, he says. Now I believe that the various arches seen by all of us were really one and the same, or parts of the same, arch. I think that this arch was a ring or arc of a circle extending across the country east and west for many miles, high up in the air, and about overhead on the latitude of the Adirondacks, which very nearly corresponds with the latitude of the parts of Montana, Maine, and New Hampshire where it was seen. The fact that the arch ran east and west would account for the fact that there was no easterly or westerly deviation at these points. But at both Duxbury, Mass., and Wayne, Pa., where it was seen, there should have been, if my supposition is true, a northerly deviation, due, of course, to parallax. And in both the cases the deviation was noticed, and furthermore, it was more pronounced at Wayne, which is farther south than Duxbury. All this would seem to point to the one arch theory, which I believe is the correct one. H. M. T.

Jan. 9, 1904.

BOOK NOTICE.

Elementary Plane Geometry by McMahon.—The Cornell series of mathematics now includes Analytic Geometry by Tanner and Allen, Differential Calculus by McMahon and Snyder, Integral Calculus by Murray, a single volume

of the Differential and Integral Calculus by Snyder and Hutchinson, Elementary Geometry by Tanner, and the new and latest book on Plane Geometry by James McMahon which has just been received. The series as a whole is strong and thoroughly modern in matter and method. In the class-room the earlier books in Calculus and Analytic Geometry have stood the test well, and won for their authors high commendation for practical worth, rigorous method and well chosen matter. The book before us has points of special interest, in the treatment of Elementary Plane Geometry. They are briefly:

1. Soundness of structural development.
2. Distinction between Euclidean space, and non-Euclidean space.
3. The meaning and true place of postulates.
4. The grouping of theorems and problems so as to unfold logically space relations.
5. The treatment of size relations as purely geometrical.
6. Euclidean doctrine of ratio and proportion is put in modern form.
7. The measurement of a circle is based on the definition of the length of a curved line in terms of a straight measuring unit.

These are some of the more prominent features of this new Geometry that will quickly catch the eye of teachers of this branch. Those instructors who *think* and prepare themselves *very thoroughly* will also be interested in the following paragraph taken from page 8:

"The postulates as defining Euclidean space. A space that fulfills the conditions embodied in the postulates and primary definitions is called a *Euclidean space* after the name of Euclid, who wrote the first systematic treatise on geometry. We can never be absolutely certain, at least with our present mode of perception, that our space is of the ideal Euclidean character, but there is no doubt that, for all human needs, it may be regarded as accurately Euclidean.

A perfect system of postulates should embody the primary notions that are necessary and sufficient to distinguish Euclidean space from other kinds of space, and to furnish a starting point from which all its properties could be derived by a chain of reasoning without further resort to experience. Euclid and the ancient geometers did not give close attention to the necessity and sufficiency of their system of conventions. They silently took for granted certain things that do not follow from previously accepted principles; and some of their fundamental conventions are not independent of each other. Modern geometers are not yet entirely agreed on a complete system of mutually independent postulates for Euclidean space, and the full discussion of this question goes beyond the limits set for elementary geometry.

Several different systems of non-Euclidean geometry have been studied, each of which dispenses with one or more of the characteristic properties of Euclidean space. The most celebrated of these systems dispenses with the 'postulate of parallels,' which will be introduced in the proper place. It should be observed that if only the 'postulate of dimensions' is dispensed with, the space is still Euclidean in character, for a Euclidean three-dimensional space may be regarded as existing in a Euclidean space of four or more dimensions, just as a two-dimensional space exists in a three-dimensional one. A Euclidean space of more than three dimensions is called a Euclidean hyper-space."

General attention is called to this new book as a basis for the study of the higher mathematics.

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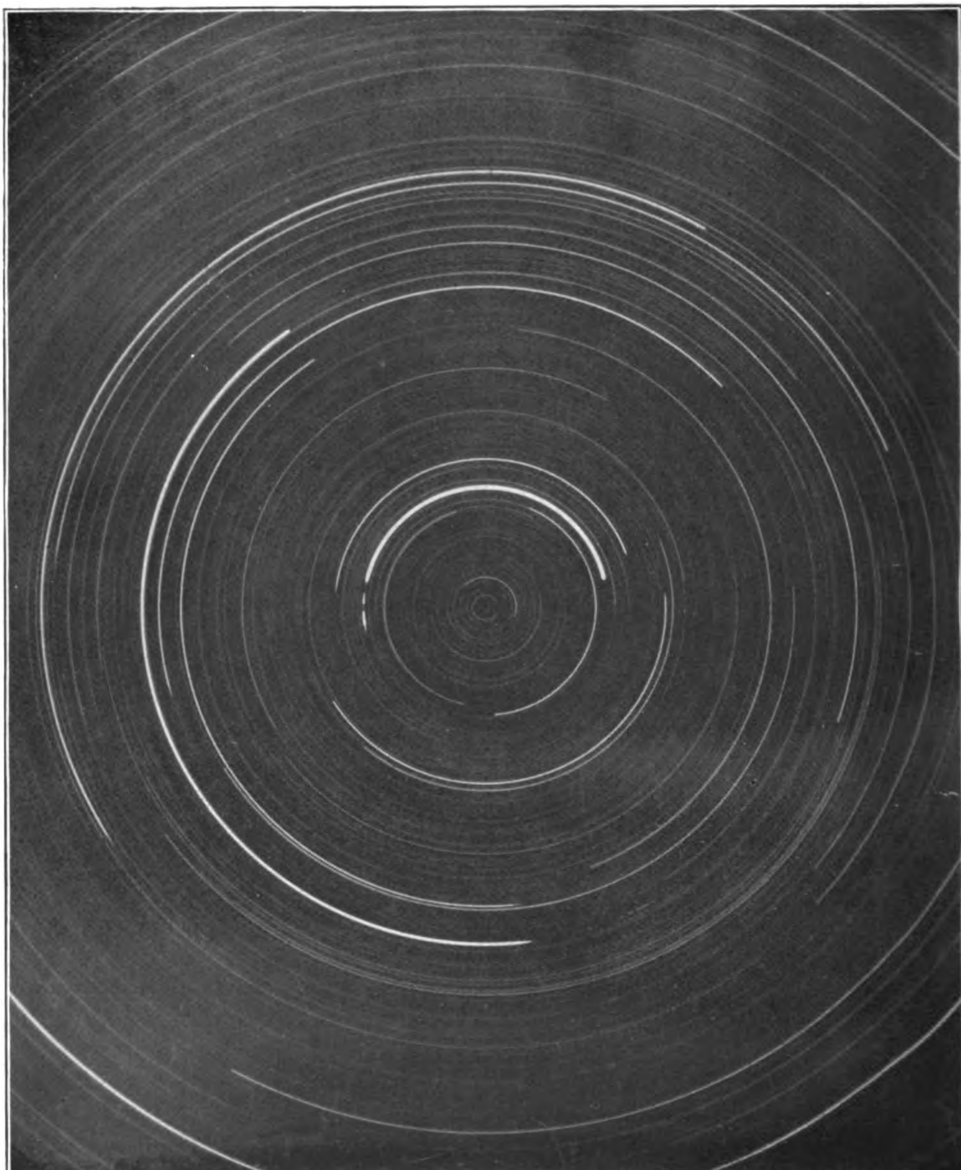
PLATE VIII



STAR TRAILS AROUND THE NORTH POLE.

Exposure 12 hours, the last hour and a half being partly cloudy. The heavy trail just above the center is that of Polaris.

Popular Astronomy.

Vol. XII No. 4. APRIL, 1904. Whole No. 114.

VIEWS OF PROFESSOR YOUNG ON THE CONSTITUTION OF THE SUN.

We have learned that Dr. Vogel of Potsdam is getting out a new and enlarged edition of Engleman's translation of Newcomb's Popular Astronomy, and that he has asked Professor C. A. Young of Princeton University, (author of Young's series of astronomical text-books), to rewrite and bring down to date for it, his views of the constitution of the Sun, given in the original edition twenty-seven years ago. Knowing this, we asked Professor Young if we could not have this revised statement for publication. He kindly acceded to our request, and, herewith, our readers are favored with a full copy of his latest views on the subject before the statement is published in German in the work mentioned above. Those acquainted with Professor Young's views given in the original edition of 1877, will be interested to notice how few important changes and corrections have been made in the rewriting. The numbers (1) (2) etc. refer to paragraphs similarly numbered in the original edition.—EDITORS.

(1). It seems to me practically certain, as a consequence of the low mean density of the Sun and the enormous force of solar gravity, that in the central portions of the body, and in fact, in all but a comparatively thin shell on the outside, the constituent substances must be in the purely gaseous state on account of the exceedingly high temperature, far above the critical points of any known vapors. But whether all the chemical elements are necessarily in a state of "dissociation," as formerly supposed, is perhaps now doubtful in view of the discovery of compounds (certain carbides, for instance) which are freely formed at the highest temperatures of the electric furnace.

Under the enormous pressure the internal gases are considerably denser than water, and probably so viscous that perhaps it may not be impossible for the nucleus to behave to a certain extent like a pitchy semi-solid globe in permitting peculiar conditions to become for a time "localized," so to speak, at special points; as seems to be suggested by the observed tendency of solar spots and other disturbances to recur at the same points on the surface.

(2 and 3). I still think it probable that the photosphere or visible surface of the Sun consists of an envelope of *clouds* formed by the condensation and combination of such of the solar va-

pors as are sufficiently cooled by their radiation into space. This envelope acts like a "Welsbach mantle" in its intense radiating power, and supplies the continuous background of the solar spectrum. The photospheric clouds are of course suspended in the surrounding gases and uncondensed vapors just as clouds float in our own atmosphere.

From the under surface of this cloud shell, if it really exists, there must necessarily be a continual precipitation into the gaseous nucleus below with a corresponding ascent of vapors from beneath—a vertical circulation of great activity and violence, one effect of which must be a constricting pressure upon the nucleus much like that of the liquid skin of a bubble upon the enclosed air. With this difference, however, that the photospheric cloud-shell is not a continuous sheet but "porous," so to speak, and permeated by vents through which the ascending vapors and gases can force their way into the region above.

As to the thickness of the photosphere, I see at present no means of determining it with certainty: it must be some thousands of miles.

I am aware that this cloud-theory of the photosphere is not free from difficulties, and that much can be said for the hypothesis proposed by Schmidt of Stuttgard, according to which the photosphere is merely an optical phenomenon due to refraction in and around a globe entirely gaseous. But it still appears to me to be almost a necessary consequence of the known laws of physics that a gaseous globe, free in space, and composed to a considerable extent of metallic vapors, must inevitably clothe itself with an envelope of cloud.

(4). The "reversing layer" and chromosphere in my view are simply the uncondensed vapors and gases which form the atmosphere in which the clouds of the photosphere are suspended, but also rise far above them. It is not intended however by the word "atmosphere" to indicate that this gaseous envelope overlying the photosphere is like the atmosphere of the Earth in its mechanical conditions. It cannot be in statical equilibrium under the action of the Sun's gravity, nor in thermal equilibrium, but rather resembles a sheet of flame,—"a prairie on fire" to use the graphic description of Professor Langley.

The so called "Reversing layer" is the thin stratum at the base of the flame-sheet, rich in all the vapors from which the photospheric clouds are formed. Here mainly, and in the depths between the clouds, the dark Fraunhofer lines have their origin; and at the beginning and ending of totality in a solar eclipse the

spectrum of this layer appears for a few seconds as the bright-lined "flash spectrum," first observed by the writer in 1870, and since 1896 abundantly confirmed by photographs in recent eclipses.

The chromosphere is the region above the Reversing layer, and is made up of the gases and vapors which are non-condensible under the conditions there prevailing,—mainly Hydrogen, Helium, and that form of Calcium vapor which gives the H and K lines in its spectrum. Very likely there may be also other gases as yet unidentified.

The prominences are merely masses of these chromospheric gases carried high above the general level by blasts and currents ascending through the photosphere and apparently floating in the lower regions of the coronal atmosphere which overlies the chromosphere. Occasionally metallic vapors (Mg., Na., Si., Fe., etc.) are projected to considerable elevations, especially in the regions surrounding (but not *in*) large and active spots; and in such cases the prominences usually show rapid changes of form and size, with distortion and displacements of the lines in their spectra.

Until very recently these spectral phenomena have been explained as due to explosive pressures, and motions in the line of sight almost incredibly violent. The recent work of Julius and others tends however to show that some of these appearances may be optical only, and due to anomalous refractions in dense metallic vapors.

(5). The corona is still to a certain extent problematical. Unquestionably it is in part an envelope composed of an extremely rare, and as yet unidentified, gas (provisionally called "Coronium"), having a spectrum characterized by a fairly conspicuous bright line long supposed to be the reversal of the "1474" line of Kirchcoff's map (λ, 5316), but lately shown to be slightly more refrangible (λ, 5304). There are also several other lines revealed by eclipse photography in the violet and ultra-violet region which are probably due to the same element.

As to the streamers, which seem to shine partly by reflected sunlight and partly by pure incandescence, it appears from their spectrum that they are not gaseous, but composed of minute particles driven off from the Sun by some repulsive force,—possibly electrical, or perhaps by the repulsive force of radiation, so recently verified in our laboratories.

Their arrangement with reference to the solar surface is obviously determined by forces which, in their action if not their

origin, are analogous to those which control the disposition of auroral streamers in our own atmosphere; but the latter appear to be purely gaseous.

(6). As regards the sun-spots, it seems no longer safe to assume that they are always depressions in the photosphere since it appears to be beyond question from observations made at Potsdam and elsewhere that occasionally, near the limb of the Sun, their heat-radiation exceeds that of the neighboring surface. Possibly this may be explained by the assumption that the absorption of the solar atmosphere for the *luminous* radiations of the photospheric clouds is very much greater than for the non-luminous, long-waved rays emitted by the spot; but the more probable inference seems to be that the spots in these exceptional cases lie at a considerable elevation so as to escape much of the atmospheric absorption. The darkening of the spots is almost certainly due to absorption, and, to a certain extent at least, this absorption is *gaseous*, and not merely "foggy;" this is indicated by the remarkable strengthening of the dark lines of vanadium and some other substances, as well as by the resolution of the green portion of the spot-spectrum into a shading, of closely packed, dark lines.

As to the cause of the spots I find none of the theories thus far suggested wholly satisfactory. Their distribution on the solar surface makes it clear that they are in some way closely connected with the peculiar law of the Sun's surface rotation, and this fact accords with the theory of Faye; but the cyclonic features demanded by that theory are certainly not obvious. It appears also that there is often a close connection between the position of a spot on the Sun's surface and conditions existing in the gaseous, but viscous, nucleus underlying the photosphere. This is indicated by the frequently observed tendency of spots to break out repeatedly at, or near, the same points upon the surface.

There is unquestionably often, perhaps usually, a powerful uprush of chromospheric gases around the edge of a spot, but seldom, if ever, through the umbra itself. Whether the spot is caused by matter descending from above, or is a "sink" in the photosphere due to relief of pressure underneath (as I used to believe), or has some other widely different explanation, I have at present no confident opinion.

I am still in doubt as to the cause of the periodicity of the sun-spots and the nature of the unquestionable connection between solar activity and magnetic disturbances on the Earth. On the

whole however I am still inclined to believe that the periodicity originates within the Sun itself: it is certainly not attributable to any planetary influences, though influences from the regions beyond our system are by no means barred.

(7). The investigations of the past twenty-five years appear to have determined the effective temperature of the Sun as not far from 6000° C., but the "solar-constant" itself seems to be much more uncertain.

Langley's value, 3.0 calories (small) per centimetre per minute, is perhaps nearest the truth; but the Smithsonian observations of 1902 and 1903 seem to require a reduction of about 25 per cent., bringing it down to 2.25.

The question of the constancy of the solar radiation, one of the most important in the whole range of Astrophysical science, still remains unsolved, but there is reason to hope that investigations now preparing, or already in progress, will soon throw light upon it. Its difficulty lies of course in its complication with the vexatious caprices of terrestrial meteorology.

As to the maintenance of the Sun's radiation there can be no doubt that the contraction theory of Helmholtz represents a *vera causa*, and is true so far as it goes; but that it is the whole truth now seems at least doubtful in view of the newly discovered behavior of radium and its congeners. This suggests that other powerful sources of energy may coöperate with the mechanical in maintaining the Sun's heat.

(8). The equatorial acceleration of the solar surface appears to me to have found its true explanation in the investigations of Salmon and Wilsing, who consider it to be a slowly dying survival of conditions, no longer existing, but once prevailing while the solar system was in the process of formation. I am aware that recently others, Emden especially, have attempted to deduce it mathematically as a necessary consequence of the constitution of the Sun. But I fail to be convinced because of doubt as to some of the fundamental assumptions.

Such in brief are my present "opinions," some of which however are held not very confidently. Time doubtless will clear up many points at present obscure; and also, for such is the condition of the search for truth, will in all probability confront our successors with new problems still more perplexing.

PRINCETON, N. J., U. S. A., C. A. YOUNG.
February, 1904.

THE DETERMINATION OF SOLAR MOTION.

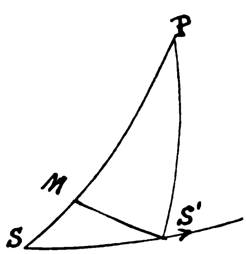
MARY W. WHITNEY.

FOR POPULAR ASTRONOMY.

In October 1897 I presented in POPULAR ASTRONOMY an outline of the problem of solar motion. In that paper no mathematical steps were given. It will be profitable, perhaps, to those readers who are familiar with the elementary principles of analytical geometry and calculus, and understand the bearing of the method of least squares upon the results of observation, if I add at this time the simpler mathematical processes which have been employed by astronomers in their attempts to answer the questions of direction and velocity of solar motion. I will include some of the results of this investigation as obtained by earlier and later astronomers.

The data upon which the investigation rests are the observed changes in right ascension and declination of stars during long periods of time, but usually expressed for working purposes in the changes for one year. Let $\alpha' - \alpha = d\alpha$ and $\delta' - \delta = d\delta$ represent these yearly proper motions in right ascension and declination.

The values for Herschel's graphic process, explained in my first paper, were obtained in the following way.



Let P denote the celestial pole.

SS′ = ρ, the proper motion, considered as taking place along a great circle.

K, the angle PSS′ which the direction of the star's motion makes with the hour circle PS. This is called the position angle of S′.

From S′ draw S′M parallel to the equator. The triangle SS′M may be regarded as a plane right angled triangle. Observation supplies SM and S′M, and we have

$$\begin{aligned} S'M &= d\alpha \cos\delta = \rho \sin K \\ SM &= d\delta = \rho \cos K \end{aligned} \qquad (1)$$

These equations give K, the position angle by which Herschel plotted the great circles SS′, whose intersections determined his first position of the apex of the Sun's way.

Equations (1) give also ρ, which is the value usually published in text books, for instance the 7″ of Groombridge 1830.

By later and more exact steps of approximation, Herschel arrived at the following values for the right ascension and declina-

tion of the solar apex;

A = 245°.9 D = 40°.4, a point near the star η Herculis.

Herschel also discussed the probable rate of the Sun's motion toward this point. He concluded that the yearly motion of the Sun, viewed at a right angle to its direction, and from the mean distance of first magnitude stars, would subtend an angle of 0″.75.

These first remarkable determinations of Herschel were followed by a method of successive approximation, known generally as Argelander's method. This method assumes values for A and D, and obtains corrections to them, ΔA and ΔD. It may conveniently be considered under three heads, and these three divisions well illustrate the steps frequently taken in an investigation, which passes from a first to a second approximation. The steps may be given in a general way as follows:

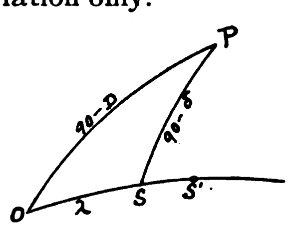
1. Given the approximate values (in our case A and D), find in terms of them some other quantity, which can also be obtained from observed data. Let us call this theoretic or computed value, K_c.

2. Find this K from the observed data. Call it K_0.

3. If the assumed values are correct, the difference $K_c - K_0$ will be zero. If it is not zero, the difference depends upon the errors in our assumed values.

When the differences $K_c - K_0$ (often called, for brevity, C — O) are small enough to be regarded as differentials, we may obtain our corrections to the assumed values by differentiating the equation which expresses the relation between K and these quantities. This is the third step, which we sometimes take even when the differences are too large to be regarded as differentials, because no more exact way is open to us.

In our special case, the quantity selected to be expressed as a function of A and D is the angle (already lettered K) which the star's proper motion makes with the hour circle of the star. For the present, we regard this proper motion as due to solar translation only.



The figure for our first and third steps is the spherical triangle whose vertices are the pole P, the star, S, and the apex of the Sun's way O. SS′ is, as before, the star's proper motion, for the time being regarded as coincident with the great circle OS.

K is the angle PSS′. The angle at P is α — A, if α denotes the

right ascension of the star. Let λ denote the angular distance of star from apex, OS.

The application of the well known formulas of spherical trigonometry, given in Chauvenet's Spherical Trigonometry § 114, and often spoken of as the "astronomical group," because of their frequent use in astronomy, gives

$$\begin{aligned} \sin\lambda \sin K &= \cos D \sin(\alpha - A) \\ \sin\lambda \cos K &= \cos D \sin\delta \cos(\alpha - A) - \sin D \cos\delta \end{aligned} \qquad (2)$$

Thence

$$\tan K_c = \frac{\cos D \sin(\alpha - A)}{\cos D \sin\delta \cos(\alpha - A) - \sin D \cos\delta} \qquad (3)$$

This solution gives also λ, which will be needed in our third step.

The second step, requiring us to obtain κ in terms of observed data, has already been shown in (1), which provides

$$\tan K_0 = \frac{d\alpha \cos\delta}{d\delta}.$$

For every star, we have now its K_c and its K_0.

The difference $K_c - K_0$ depends upon the errors ΔA and ΔD. But it does not depend on these alone. It is caused, secondly, by the fact that the star has a motion of its own, called its peculiar proper motion, which does not carry it along the circle OS. This peculiar proper motion may run in any direction. Thirdly, the difference depends upon the small, unavoidable errors of observation which we call accidental errors. For the time being, however, let us consider only the first of the three.

To obtain, on this supposition, the relation between $K_c - K_0$ and the errors in A and D (all now regarded as differentials), we suppose our spherical triangle subject to variation through the change in the position of O; i. e. $90 - \delta$ is the only constant part of the triangle. Applying the general differential formula for the spherical triangle,

$$\sin a dB = \sin C db - \cos a \sin B dc - \sin b \cos C dA,$$

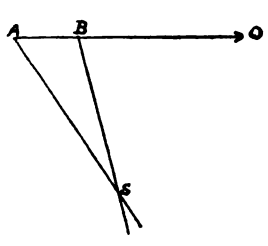
where dc, in our case, is zero, and making substitutions for sin O and cos O, by aid of the "astronomical group" already referred to, we obtain,

$$dK \sin\lambda = \frac{\cos\delta \sin(\alpha - A)}{\sin\lambda} dD - \frac{\cos D \sin\delta - \sin D \cos\delta \cos(\alpha - A)}{\sin\lambda} dA \cos D. \quad (4)$$

Every star involved gives an equation of the form (4). This, then, is the relation between our known values, dK, and our desired values dD and dA, if we ignore the star's own motion and the accidental errors of observation. But what are we to do about these? Here the method of least squares comes to our help. It can deal with the accidental errors by its principle of probability, and at the present time we are forced to let it deal in like way with the stars' own motions. Since we have reason to believe that most of the stars are travelling in all possible independent directions, i. e. are controlled by no common centers of attraction, we may subject them also to the theory of probability, and assume that the method of least squares will eliminate them. In a large degree the results have justified this assumption. If they are not thus eliminated, there will remain some indication of their vitiating effect, as will be later shown.

The solution by least squares of the group of equations (4), one for each star, will give the most probable values of dA and dD, which, applied to the assumed A and D, determine the most probable position of the apex, as based upon the stars involved in the investigation. Argelander applied this method in 1838 to the proper motions of 390 stars. He first selected about 500 stars, which by comparison of Bradley's catalogue (1755) with Piazzi's (1800) showed a sensible proper motion. Of these, he observed himself, about 1830, the 390 used in his discussion. Thus an interval of 75 years was secured for the determination of proper motion. His published results are: A = 259°.8 D = 32°.5. This locates the apex between π and μ Herculis.

Argelander did not consider the rate of solar motion. But a little later (1844) Otto Struve approached the subject in the following way. In the first equation of (2), he substituted $\sin K = \frac{d\alpha \cos \delta}{\rho}$, as given by (1) and sin λ, as given by the accompanying figure.



Let d denote distance of star, and l the Sun's linear velocity per year, AB, temporarily assumed, as before, to be the sole cause of proper motion. Under this assumption ASB = ρ. BAS is the λ of (2), the angular distance of star from apex.

Therefore

$$\frac{\sin \lambda}{\rho} = \frac{d}{l}$$

and

$$d\alpha \cos \delta = \frac{l}{d} \cos D \sin (\alpha - A) \qquad (5)$$

A similar equation could be formed for $d\delta$. If d were known, l could be derived. In 1844 little accuracy could be assigned to stellar parallaxes, and Struve did not attempt, as Herschel did not, to find l. With both, $\frac{l}{d}$ was treated as the unknown quantity. Struve assumed certain ratios for the distances of stars of different magnitudes, which his father W. Struve had already published. He obtained, for the mean distance of stars of the first magnitude, $\frac{l}{d} = 0''.34$, a value much smaller than Herschel's.

By regarding the Argelander values of A and D as approximate, i. e. $A = A_0 + dA$ and $D = D_0 + dD$, Struve entered in his equations two other unknown quantities, dA and dD. In fact, he introduced these before he made his final least squares solution, and obtained them at the same time with $\frac{l}{d}$. His investigation was based upon the proper motions of 400 stars.

His values for the apex were,

$$A = 261°.4 \qquad D = 37°.6$$

In 1847 Galloway published another determination of A and D, following Argelander's method, and employing mostly southern stars. He found

$$A = 260°.0 \qquad D = 35°.4$$

In 1856 Mädler renewed the discussion by the Argelander method, making use of 2163 of Bradley's stars, which were reobserved at Dorpat. His values are:

$$A = 261°.6 \qquad D = 39°.9$$

These results, from Herschel to Mädler, present a remarkable agreement, considering the nature of the data involved, and the unknown influence of peculiar proper motion.

The more modern methods will be considered in a subsequent paper.

JESUIT ASTRONOMY.

WILLIAM F. RIGGE, S. J.

FOR POPULAR ASTRONOMY.

PART II. THE RESTORED SOCIETY 1814-1904.

The Society of Jesus, suppressed in 1773, was restored in 1814. The conditions confronting it had changed considerably during

its extinction, and its progress in all directions was beset with new and greater difficulties. Not to mention the necessity of beginning life over again, and passing through the stages of infancy and adolescence unto maturity, the sciences were being modernized and specialized, and books and instruments and courses of study were increasing in number and in technical character. Competition was becoming keen, and means were proportionately smaller. The restored Society was obliged to build its colleges generally at its own expense, as the race of founders and benefactors was practically extinct, so much so, in fact, that whereas tuition had formerly been free in its colleges, special papal dispensation was now necessary to allow fees to be received in them for their support.* Persecutions and confiscations were as frequent as ever, and even today the Society of Jesus is either outlawed or barely tolerated in most of its former most flourishing European provinces. Its scientific, and notably its astronomical activity was therefore, and is yet, very much embarrassed by the lack of means and of sufficient leisure, no less than harassed by positive opposition and persecution. However, the old spirit of the Order is fully alive, and in the short space of practically three quarters of a century the new Society has nobly emulated the deeds of the old.

In presenting to the reader the astronomy of the new Society of Jesus from the time of its restoration in 1814 until the present year 1904, I shall follow the same general plan as in the preceding sketch of the astronomy of the old Society, 1540-1773. The short duration of the restored Society will be sufficient reason, should my list of facts appear meagre. My reason for presenting them is the opportuneness of annexing this second part to the translation of the first, and the natural and very reasonable desire of the reader to know whether the Jesuits of today have kept up their standard of excellence and are as fully abreast of the age as their brethren of yore.

Let me then begin with the

Observatories.

The number of observatories in the new Society of Jesus already rivals that of the old. While some of these are observatories in the technical sense, in which the directors, with one or more assistants, are able to devote much or all of their time to

* Of the 27 Jesuit colleges in the United States, the one at Omaha is the only one which is endowed. The endowment of this is due to the munificence of the Creighton family.

special research, others on the other hand are only college or students' observatories, the directors of which may or may not have the leisure or the inclination to undertake continuous or even occasional work. The equipment of the observatories of the first class I shall describe somewhat fully, but pass rapidly over those of the second.

Rome, Italy.—"The Roman College has always been the home of science. Here Father Scheiner gathered the material for his famous work, Rosa Ursina. Here also at the western end of the present church of St. Ignatius Fr. Gottignes (Brussels 1630-Rome 1689) discovered markings on Jupiter and observed comets. Here Fr. Asclepi (Macerata 1706-Rome 1776) wrote on stellar aberration and the orbits of comets. Here, in what is now called the *Kircher* museum, Fr. Borgondius (Brixen 1679-Rome 1745) was wont to observe the stars, and the sun dial erected by Fathers Maire and Boscovich is still to be seen.

But this place was entirely unsuited to the work done and projected. Benedict XIV intended to build and equip a better observatory, but the storm then gathering about the Society of Jesus put an end to these plans.

After the Suppression Joseph Calandrelli, a secular priest and an excellent mathematician, succeeded in carrving out the greater part of all that had been planned, and he may therefore be rightly called the founder of the Roman College Observatory, for in 1787 he erected the observing tower which is at the east end of the college. But as his means were very limited he was unable to equip it except with the small instruments he had used in the private observatory of his patron Cardinal Zelada. Later on the large zenith sector of Fr. Boscovich came into his hands, and he was the first to observe and establish the latitude of the place with it.

The large partial eclipse of the Sun of February 11, 1804, was a fortunate occurrence for Fr. Calandrelli, because it brought Pius VII into his observatory. The Pope was so much interested in what he saw that he promised personally to defray the expenses of a better equipment.

When Leo XII in 1824 gave back this observatory to the Society of Jesus, Fr. Calandrelli departed with his assistants Conti and Ricchebach, and took the greater part of the instruments along with him to the college of St. Apollinaris, to the disappointment of the Pontiff who had expected that Calandrelli at least would remain. The Pope would perhaps have erected another telescope in the vacated place, but he died three years

later."*

The Jesuits appointed Fr. Dumouchel as director, supplied him with some instruments and gave him Fr. De Vico as an assistant. The management of the observatory devolved more and more upon Fr. De Vico until he became the official director at Fr. Dumouchel's death in 1840. By means of a Gambey theodolite Fr. De Vico determined the position of the observatory more accurately than had been done before. He was an active observer of the planets, Venus and Saturn especially, and of comets. He also began a Durchmusterung of the stars down to the eleventh magnitude. He added an Ertel meridian circle to the 6-inch Cauchoix equatorial, and introduced the custom, which was widely imitated, of firing a cannon to indicate the moment of noon.

In 1848 the revolution drove the Jesuits from Rome. Fr. De Vico fled to France where he was enthusiastically received by Arago. In England he was offered the directorship of the observatory at Madras, but he preferred to go to Georgetown College, Washington, D. C. Being called on business to London, he died there November 15, 1848, at the early age of 43.

Fr. Secchi, who also had found refuge in Georgetown, was recalled in 1849 to take charge of the Roman Observatory. With the means liberally supplied by Pius IX and the Society, he transferred the observatory in 1853 to the place his predecessors had selected, that is, he built it upon the east and south walls of the college and upon the principal pilasters of the church of St. Ignatius. In 1856 he published his first observations upon double stars, and continued to observe them until 1875. In 1860 he began his spectroscopic work. He observed the total eclipse of the Sun of July 18, 1860, in Spain, and along with Mr. De la Rue, who was stationed about 250 miles away, was the first to apply the photographic camera to this purpose. The result proved the prominences to be solar appendages.† Fr. Secchi's other labors will be found elsewhere in this article.

In 1870 the Italian government seized upon Rome, and as usual the property of the Jesuits was confiscated. The government however was forced to reinstate Fr. Secchi in his observatory, owing to the energetic protests of the scientific world. After the Roman college and its observatory were taken away from them, the Jesuits gradually established themselves at the Gregorian University, where Fr. Adolph Müller now possesses a

* Vox Urbis, 1 March 1903, a bimonthly Roman newspaper written in Latin.

† Clerke's History of Astronomy during the Nineteenth Century, second edition, page 211.

10-inch and a 4-inch Merz telescope. The position of this private observatory, Borgo S. Spirito, 12, is very unfavorable. With no assistants, with meager means of subsistence and daily lectures at the university, Fr. Müller has little time for special work. He has however published quite a number of papers in various journals. He is now busily engaged in preparing for the press the second volume (about 600 pages octavo) of his "Elements of Astronomy."

Kalocsa, Hungary.—The Haynald Observatory owes its existence to the munificence of Cardinal Haynald, Archbishop of Kalocsa. The possession of a 4-inch telescope with which His Eminence delighted to look at the heavens, gradually led up to the idea of founding and equipping the present fine observatory. The building was begun in 1878 and the instruments ordered under the direction of Dr. Nik. v. Konkoly, of O'Gyalla. In September of that year Father Carl Braun arrived and became the permanent director.

The observatory proper occupies the second floor of the Gymnasium. The 4-inch Merz equatorial is mounted in a 3 meter (10 foot) cylindrical dome, and a 7-inch Merz equatorial similarly in a 4 meter (13 foot) dome. A meridian room contains a small transit, and a prime vertical room a universal instrument reading to 2 seconds. The latter may also be mounted upon a pier outside which commands an extensive view of the neighborhood.

The observatory is well equipped for solar work, which has been continuously and systematically pursued since 1884. There are several spectroscopes, a small Vogel with two prisms, a Browning direct-vision with two quintuple Amici prisms, and a large one with ten prisms. In the latter instrument any even number of prisms may be used with automatic adjustments. There are also a position and a double-image micrometers, a Zöllner astrophotometer, a Glan and Vogel spectrophometer, a reflecting circle, chronograph, and several clocks. Fr. Braun's resourcefulness has made all these instruments very convenient to use.

In 1885 Fr. Fényi, the present director, took charge of the observatory, and made the solar prominences the object of his special research. Besides three folio volumes of almost daily measurements of the prominences, and two volumes of meteorological observations, he has written more than a hundred technical articles in various scientific journals, especially in the *Memoria della Società dei Spettroscopisti italiani.** His most important paper

* 24 have appeared in this journal, 11 were read before the French Academy, etc.

is probably the one which appeared in the *Astronomische Nachrichten* No. 3355, and in the *Astrophysical Journal*, Vol. IV., pp. 18-37, under the title "A new point of view for regarding solar phenomena and a new explanation of the appearance on the surface of the Sun."—Father Fényi has also added an excellent meteorological department to his observatory. He is a member of the Astronomische Gesellschaft, the Hungarian Literary Society, the Academia Pontificia dei Nuovi Lyncei, the Montevideo Instituto solare, etc.

Fr. Schreiber became assistant at the Haynald Observatory in 1891. Notwithstanding his failing health he engaged in much literary and scientific research. Besides the first part of this present paper on Jesuit astronomy, he wrote on the solar work of Fr. Scheiner, and the lunar map of Frs. Riccioli and Grimaldi, and invented the ceraunograph for detecting and registering flashes of lightning at a great distance.* His principal astronomical occupation was the observation of sun-spots and the determination of time with the transit. He died March 10, 1903. Fathers Esch and O'Connor have lately become assistants to Fr. Fényi.

Whalley, England.—The observatory of Stonyhurst college dates back to the year 1838-39, when a building consisting of an octagonal centerpiece with four abutting porches or transepts, was erected in the middle of the garden. But it was not until 1845 that a 4-inch Jones equatorial was mounted in the dome. Meteorological observations were begun as early as 1844, and magnetic in 1856 by Fr. Weld. In 1867 the astronomical department was removed to a corner of the garden, and an 8-inch equatorial set up. The work under Fr. Perry's management was chiefly directed to the daily study of the solar spots, faculæ and chromosphere. At his death in 1890 Fr. Sidgreaves became director and began work on stellar spectroscopy. Fr. Cortie has also distingtished himself at the observatory. Fathers Sidgreaves and Cortie are, as Fr. Perry was, prominent members of the Royal Astronomical Society and are frequently chosen to fill official positions. Their writings, technical as well as popular, have given quite a name to the observatory.

At present the equipment consists of a 15-inch equatorial refractor with "Father Perry Memorial" glass, a Jones 4-inch and a Clark 5-inch equatorial refractors, a Cassegrain 9½-inch altazimuth reflector, a 7-inch Newtonian reflector, two transits,

* Report of the Director of the Philippine Weather Bureau, 1902, Part II., p. 29.

two sidereal clocks, a chronometer, a heliostat, two direct-vision spectroscopes, one by Browning and the other by Hilger, a large Troughton and Simms spectroscope with four compound prisms by Hofmann, an automatic Browning spectroscope with six prisms and a Christie-Hilger half-prism, a photographic grating spectroscope by Hilger, and a 4-inch disk prism mounted on the 4-inch finder of the equatorial.

Washington, District of Columbia, United States of America.— The observatory of Georgetown College is one of the oldest in the United States. Founded in 1842–43 it was almost coeval with the Naval Observatory at Washington, while the very oldest observatory, that of Williams College, precedes it by only seven years.

The main building is of brick, and consists of a central portion which is surmounted by a dome covering a 12-inch Farth equatorial, and two wings, the western for a 4.5 inch Ertel transit instrument, and the eastern for a 9-inch Saegmüller photographic transit. The 4-inch Troughton and Simms meridian circle, which had been in the eastern wing for many years, is now dismounted. A frame annex on the east contains a 6-inch photographic zenith telescope, and a small dome houses the old 5-inch equatorial which was originally set up in the central portion of the main building. There are many smaller instruments and attachments, a Fauth chronograph, a Riefler clock in a partial vacuum, and a number of other clocks. The astronomical library on the second floor of the central portion is very complete and up-to-date.

The observatory was built by Fr. Curley, the first director, whose determination of the longitude in conjunction with Sir G. B. Airy, the Astronomer Royal of Greenwich, England, was made by observing a series of transits of the Moon, and was later on shown by the electric telegraph to have been correct within three-tenths of a second.

The revolution of 1848 sent some assistants to Fr. Curley, the ablest being Fr. De Vico, who however remained but a few months, Fr. Sestini and Fr. Secchi. The last taught physics for a year and made original researches in electricity. His treatise on "Researches in Electrical Rheometry" was published in 1852 in the Smithsonian Contributions to Knowledge, and was the first work from his able and untiring pen.

Fr. Sestini began observations on the colors of the stars, a memoir on which he had published while under De Vico at Rome. In 1850 he observed the spots on the Sun for more than a month and sketched the changes in the Sun's surface. These drawings

were lithographed and published by the Naval Observatory. Father Sestini's literary activity was chiefly employed in mathematics, in which he wrote a series of eight text books, and in the translation and editing of works of piety.

In 1852 Fr. Curley published a volume of 215 pages in quarto entitled "Annals of the Observatory of Georgetown College." With this book, investigation and original work ceased at the observatory for a while, the civil war and the construction of the new college preventing the faculty from paying due attention to the observatory and its instruments.

The year before the centennial celebration of the college in 1889, the observatory entered upon a new and brighter phase of existence. From having been for so long a time a students' observatory, it was henceforth devoted to special research. Fr. Hagen was appointed the director and made stellar photometry his chief work. His numerous articles upon that subject and his 'tlas Stellarum Variabilium testifv sufficiently to his diligence and to his ability. In 1890 Fr. Fargis became his assistant and perfected the photochronograph, with which extended work was carried on in the transit and the zenith telescope. In 1891 Fr. Hedrick was added to the staff.

Valk berg, Holland.—At the northeast corner of St. Ignatius College, upon walls built especially strong for the purpose, a 9-inch equatorial was erected in 1896 under a revolving dome. This instrument possesses several interesting features. The center-piece of the tube, the cell and the eye end are of aluminum. The driving clock and the pier are of the Lick type. The lens is by Cla y and the mounting by Saegmuller of Washington, D. C. Thi equatorial was on exhibition at the World's Fair in Chicago. ; lightness and convenience contrast very favorably with older instruments of equal or even smaller aperture, and it was probably the first American telescope imported into Europ . Its sho focal length (9½ feet) renders it especially fit for the observation of variable stars, on which snbject Fr. Hisgen, the first directoı, 1897-1902, and Fr. Esch, 1898-1902, have writt n many articles for the *Astronomische Nachrichten.* The pres nt director is Fr. Baur.

Besides the 9-inch equatorial there are a 5-inch telescope with an altazimuth mounting, a Breithaupt theodolite for time observations, a sidereal clock, a chronometer, a chronograph, etc.

Fr. Kugler, the professor of mathematics, has written several most valuable papers on ancient Assyrian astronomy, the criticisms of which have been very commendatory.

The following observatories have been completed but a short time ago, and one is even now in process of erection.

Manila, Philippine Islands.—The Manila Observatory may be said to have formally begun its meteorological service in 1865, although observations had been made many years previously. In 1881 it was officially approved by the government of Spain, and in 1901 by that of the United States. The meteorological importance and efficiency of the Manila Observatory far overshadows its astronomical. This is due to many causes, prominent among which are the exceptionally favorable situation of Manila in the Eastern typhoon path, and the governmental approbation and support of the meteorological department. On the other hand astronomy has by no means been neglected.

As early as August 18, 1868, three Jesuits from Manila, Fathers Faura, Nouell and Ricart, observed a total solar eclipse in Mantawaloc-Kekee and secured some excellent photographs and details of the prominences.*

From 1880 up to the present time two very valuable services have been rendered to the public. First, the official time has been given to the city of Manila. After the American occupation this service was extended to all the telegraph stations throughout the islands. Second, about a hundred ship chronometers are annually compared and rated at the observatory free of charge.

In 1894 Fr. Algué began to complete the astronomical equipment, which then consisted of several sextants, portable visual and photographic telescopes, theodolites and a meridian circle reading to seconds. A new and special building was erected at an expense of nearly 40,000 dollars. It consists of three portions devoted respectively to the transit, the equatorial and the chronometers. The equatorial is of 19 inches aperture, the objective being by Merz and the mounting by Saegmuller. The attachments to this instrument are a Toepfer spectrograph constructed in Berlin and like the one at Potsdam, and another by Hilger in London, with a grating 3 inches long. The large dome was made in Barcelona, and erected in Manila in 1898. Three other domes are also to be built for other instruments.

The reflecting zenith telescope invented by Fr. Algué in Georgetown, was used by him in Manila for investigating the variation of latitude for fully two years. At the death in 1897 of Fr. Faura, who had been director for a long time, Fr. Algué was taken away from his astronomical labors and made director of

* Spectrum Analysis by Dr H. Schellen, New York, 1872, p. 225, et seq.

the entire observatory. He is rendering indispensable service to the shipping interests of the Far East by his weather predictions. His barocyclonometer is carried on every ship. In 1900 he came to Washington along with Fr. Clos at the invitation of the government in order to supervise the printing of the large work "El Archipielago Filipino," and now he is at St. Louis preparing a Philippine exhibit for the World's Fair.

Fathers Brown and Zwack have lately been made assistants at the Manila Observatory.

THE CREIGHTON UNIVERSITY,
OMAHA, Neb.

CONCERNING THE SPECTRA OF THE NEW STARS.

H. EBERT.*

Among the most peculiar phenomena of all the astrospectral analyses belong undoubtedly the spectra of the new stars. The more details the great spectrographic aids of modern times have made known in these spectra, viz. in those of Nova Aurigæ and of Nova Persei, the less do they seem capable of being united and of being explained by simple hypotheses. The fundamental type of these spectra is the combined double spectrum consisting of bright lines shifting toward red, and appearing at the same time with these, dark lines of the same element shifting toward violet. This type seemed to demand according to Doppler's principle the existence of at least two heavenly bodies, of which the one must move with greater velocity away from us, the other toward us. But why the one should be distinguished only by lines of emission and the other by lines of absorption offered another grave difficulty for explanation. When it became perfectly clear, that the line-shift of different elements, yes even the shift of the lines of the same element, e. g. of hydrogen, when referred to the Doppler principle of movements in the line of vision yielded different velocities which often did not even agree with regard to the signs, then it was seen that an entirely different principle must be sought. And so J. Wilsing undertook an explanation of the typical spectrum of the new stars on the basis of experiments in which the high potential discharges of Leyden jars between metal electrodes took place under water. In this manner one does in fact obtain spectra which have a great likeness to those of the

* Translated by Miss Isabella Watson, Professor of French and German, Carleton College.

new stars. But if the aforementioned investigator refers the effect thus brought to light to increase of pressure, this explanation might be questioned. G. E. Hale, who let the high potential alternating current of a transformer pass between steel bars with flattened ends under water, and who photographed the resulting spectral phenomena by means of a large concave grating, comes to the conclusion, that the pressures in the spark-distances employed by him can not possibly have been so high that one could explain the shifting of the lines actually observed and corresponding to the experiments of Humphreys and Mohler. Rather it appears from his experiments that the aforementioned phenomenon has a very close connection with the absorption phenomena in the cooler envelopes of vapor surrounding the electrodes; the combined spectrum is obtained as a transition type from the bright-line spectrum to the dark-line spectrum by the addition of salt to the water, and thus without any increase of pressure. N. Lockyer also, who repeated the experiments of Wilsing and varied them in many ways can not agree with Wilsing's conception. Finally, H. Konen has exhaustively studied the influence of the most widely differing conditions of discharge on the appearance of spectral lines, and he comes to the conclusion with regard to the spark discharges emitted under water, that increase of pressure and the broadening perhaps connected with this do not suffice for the explanation of the observations.

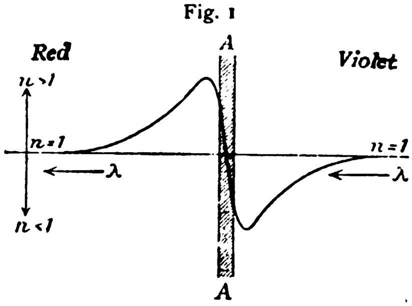
My own experiments in this line led me to the same results. In the bottom of the zinc tub in which the electrodes were held in place from above by movable supports, I fastened under the spark-gap a mirror at an angle of 45°, and opposite this in the tin side of the receptacle I arranged an opening closed by a disk of looking-glass; so the spark-gap was always seen from below; a telescope objective threw the light on first the horizontally and then the vertically placed slit of the different spectrum apparatus used in the experiment. On the under side of the tin tub a pipe was soldered, which, by means of a rubber tube, established communication with the vessel containing the filling fluid (generally water). By raising and lowering the same it was possible to regulate with great exactness the level of the liquid in the discharging vessel and to study the phenomenon while the path of the spark was sunk more or less deeply in the liquid, or just touched the surface of the liquid, or finally was entirely outside of it. The discharges were made by a large Topler induction machine with twenty rotating and forty stationary plates, by means of the parallel action of two very large Leyden jars; in

front of the spark-gap was arranged a spark micrometer, through which the discharge distance was constantly regulated at the same height. The result of many experiments with this arrangement was that the effects of pressure are not sufficient to explain the phenomena.

Another principle of explanation might, as I believe, account in an unforced way for the abnormally great line-shift appearing in the experiments just spoken of, as well as for the appearance of the characteristic double spectra. This principle depends upon the observing of the anomalous dispersion which selective absorbing media exert on the path of rays of light. W. H. Julius has already introduced this phenomenon in several works on the explanations of certain phenomena of solar physics, particularly that of the protuberances; I should like to show that anomalous refractions in absorbing vapor-envelopes under certain circumstances can also very effectually influence the distribution of brightness in the spectrum in the vicinity of the maximum absorption band; this is however just the matter in question with regard to the appearances referred to, especially with regard to those which are typical for the new stars.

Christiansen and Kundt, the discoverers of the anomalous dispersion, had already found, that a medium which possesses for a certain range of wave-length, A (fig. 1), a pronounced absorption band, possesses then when it appears as a refracting medium, for all greater wave-lengths a refracting power increasing abnormally with the approach to the absorption maximum; for the shorter wave-lengths the refracting power is so much decreased that it diverts the wave-lengths situated toward the violet much less than those situated toward the red.

Fig. 1



The metal vapors have strongly marked absorption bands corresponding to their sharp lines of emission; from them, of course, very powerful anomalous dispersion might be expected, even though it is not always easily detected. It is to be attributed only to the experimental difficulties that the number of metal vapors in connection with which the phenomenon in question was known could remain for a long time so small. I pointed out a little while ago that anomalous dispersion is not only very generally diffused in the metal vapors, but also that it extends its

influence in them to a very large range of wave-length, and indeed much farther than could be reached from the influences of movement in the line of sight or from effects of pressure.

R. W. Wood has illustrated by photogram in the case of sodium vapor the influence of such vapor-refractions on extended spectrum fields and I myself have done the same in the case of potassium vapor.

First of all, it is true, only a very few direct measurements of the refracting power are at hand. Such measurements have been made for sodium by H. Becquerel and R. W. Wood, and for potassium by me. Becquerel finds the refraction index for rays which lie toward the red from D_1, $n = 1.0009$; for rays which are toward the violet from D_2, $n = 0.99865$, both indices being referred to the flame-gases surrounding the sodium vapor. The exponent of the same in relation to a vacuum Becquerel reckons at 1.0001, so that the refraction quotients reduced to a vacuum become respectively 1.0010 and 0.99875. R. W. Wood could generate in an atmosphere of hydrogen much denser vapor-masses for which he obtained refractive indices up to 1.0024 and 0.9969 respectively, relative to hot hydrogen. Putting the index of refraction of the latter also at 1.0001, which certainly is nearly right, we have resulting the indices 1.0025 and 0.9970, respectively, when referred to a vacuum. With the 90-degree potassium vapor prisms which I used, I could get from my photogram for the K_α-line, $n = 1.00166$ and 0.99834 respectively; and that with only moderate thickness of vapor, through which still enough light passed so that distinct effects on the somewhat slowly acting plate sensitive to infra-red rays were obtained in a short time. The surrounding of the vapor consisted here also of heated hydrogen, so that the result is $n = 1.00176$ and 0.99844 referred to inter-stellar space.

It is to be noted that in all cases for the rays on the violet side of the region of absorption, for the "higher vibrations," as we will briefly say in analogy with acoustics, refractive indices are obtained which are less than one (1). Here also comes in the curious case that the vapor itself as compared with the vacuum appears as the optically thinner medium; a glance at the course of the dispersion curve shows further that the relative refracting power of the vacuum as compared to the medium increases with the approach to the territory of absorption. On the other hand the experiments teach that this right branch of the curve gets deeper and deeper as the vapor becomes specifically denser. The mechanically denser vapor-envelopes become therefore optically

less and less dense. There is no contradiction in this, though Kundt himself found with solid metals refraction exponents smaller than one (1); according to the electro-magnetic theory of light this apparent anomaly is connected with the abnormal dielectric properties of the metals, in isolated cases probably with the peculiar magnetic properties also.

When one considers that the refraction exponent of the air under atmospheric pressure with relation to the vacuum is just 1.0003, then one recognizes that the refracting power of metallic vapors is a very high one; in the cases mentioned it amounted in the sodium vapor to 8 fold, in potassium vapor to 6 fold that of the air. Consequently more extended layers of such metal vapors, as we may suppose them in the cosmic light sources, must cause very important deviations of the rays. At the same time it is to be remembered, that according to all theories of anomalous dispersion we must regard these deviations as connected with sufficiently strong absorption; it is further to be noted that it only affects the regions of the spectrum neighboring on an absorption line; in these if the refractive index deviates notably from unity to the one side and then to the other, yet the vapor hardly influences the rays of the other wave-lengths perceptibly, since for these the refraction exponent immediately becomes exactly one (1) again and the refracting power becomes null.

In order to recognize how the anomalous dispersion in metallic-vapor masses can affect the distribution of brightness in the spectrum we will now look at the case as illustrated in figure 2.

A metallic-vapor *prism* PP, such as one can manufacture for sodium, potassium or metallic lithium of considerable density by means of the blast-burner suggested by Winkelmann, *stands* with one surface close before the carbons of an arc-lamp B; the whole is surrounded by screens suited to the height, and by means of a lens the light is allowed to fall on the slit placed at a greater distance from the prism edge K. In the figure is drawn on the left the course of the rays for the deeper vibrations bordering on the absorption region of the vapor; on the right those for the higher vibrations under the supposition of a homogeneous density in the interior of the prismatic mass of vapor. Through the first named rays the light of the carbon arc is turned from both sides toward the spectrum apparatus (fig. 2*a*); and this receives thus more light in the corresponding spectral region than in the parts of the spectrum which go without refraction through the vapor; the brightness increases about in proportion as the sur-

face of B increases, which by means of the bending of the rays in the prism can send more light to the spectrum apparatus. In the direction of the red in the spectrum, there appears thus an important brightening of the continuous spectrum constantly increasing toward the line of absorption. The rays that are sent out from the white glowing carbons B and that have a greater number of vibrations than those peculiar to the vapor molecules, undergo on the other hand such refraction (fig. 2, *b*) that they do not reach the observer at all or at least only in very diminished number; hence one part in the spectrum is here entirely lacking, or the brightness of the same is very much reduced in comparison with the other parts of the spectrum. The apparent shadow lying in such a manner over the spectrum exceeds by far the actual absorption-space A, as a glance at fig. 1 at once shows. In this form is the phenomenon in question most easily proved by experiment and brought to demonstration.

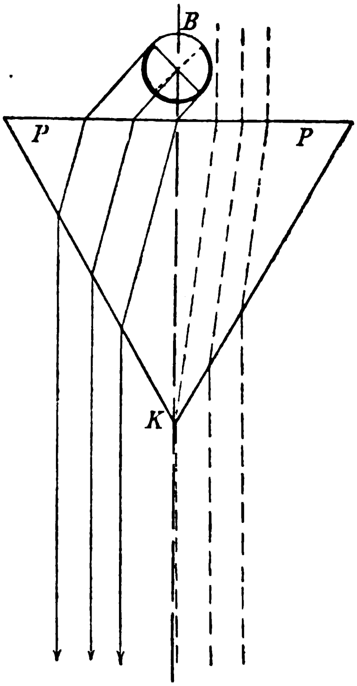


Fig. 2 a. Fig. 2 b.

Even for this simple example astrophysical applications are conceivable. If B should be a single cloud of the photospheric network, and PP, on the other hand, a thicker absorbing vapor mass lodged over it by wave, or whirling movements in the photosphere of the Sun, and if the point K of the Sun's disk is thrown by the telescope objective on the slit of the spectrograph, then there may appear in the spectrograms, toward the red side of the same, transitory brightenings of the dark absorption lines corresponding to the vapor. Thereby are at once explained abnormities in the solar spectrum such e.g. as were found recently on the plates of the Yerkes Observatory.*

* G. E. Hale, *Astrophys. Jour.* 16 p. 220-233, 1902: compare especially p. 222 and 223 above. On the edges of the dark lines λ 3884.64 and λ 3896.21 there appeared on the side toward the red, bright lines, through which attention was turned to the anomaly before us. The explanation which W. H. Julius gives of the same (in the same place 18, p. 50-64, 1903) is in principle entirely analogous to the one appearing here.

If two luminous masses B (fig. 2) were present, lying behind the points PP, then the reverse must happen; the dark absorption lines must brighten on the edges toward the violet; between these lies the case of symmetrical broadening with central reversal.

The same holds good for the above mentioned example of the condenser-discharges taking place under water. If one causes sparks or alternating current discharges to take place between metal electrodes under a liquid, he obtains cooler and proportionally strong absorbing envelopes of metallic vapor. Immediately against the electrode surfaces themselves the metallic vapors are densest at every separate discharge; then follow layers which con-

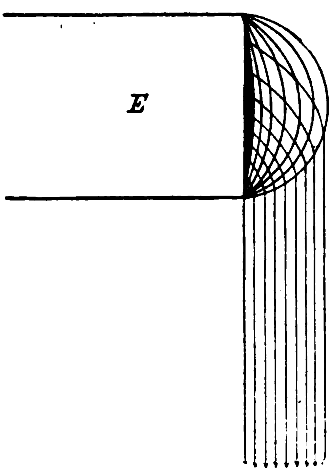


Fig. 3 a.

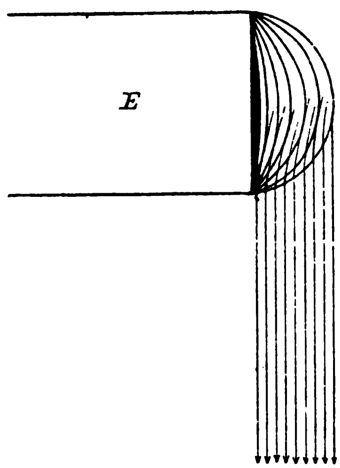


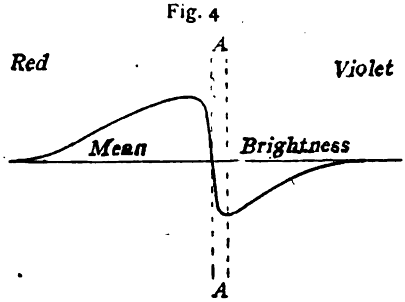
Fig 3 b.

tain less and less vaporized metal in the unit of volume. By the figures 3*a* and 3*b* this distribution may be represented in a perfectly schematic way in the case of electrodes EE flattened at the front; in these figures the lines bending farther and farther out to the right are to indicate the separate layers becoming less and less full of vapor.

The researches of Hartmann and Eberhard have very recently shown how quickly, indeed, the intensity of a metallic line decreases with the density of the vapor. Hence, if we look at such a spark-gap from the side we may expect such a ray path as would result if we were to introduce opposite the point of observation, which may be below, rays from outside into the vapor envelopes and were to trace their refraction through them; this is the case for each electrode E; in fig. 3*a* for the deeper vibrations with relation to a metal line with $n > 1$, in fig. 3*b* for the higher

vibrations for which $n < 1$. According to the principle of the reversibility of the path of light, the path of those rays which go out from the points struck in the first case into the spectral apparatus must be reversed. One sees then, that the rays for which the inner layers become more and more refrangible (fig. 3*a*) bring light from the hotter deeper layers, in fact from the inner electrode surfaces themselves into the apparatus; the rays (fig. 3*b*) for which the refraction index of the vapor layers is smaller than that of the surrounding envelope of gas (in sparks under water consisting of course mainly of hydrogen) *yield* on the other hand only light which comes from the cooler outer layers. Fig. 3, it is true, presents only one special case which perhaps seems but little probable. But one can easily draw other distributions and apply to them the preceding observations. For instance, if two flattened electrodes are standing opposite each other at a very small distance in comparison to their thickness, as was the case in the experiments of Hale just referred to, then the metallic vapors will spring out from the narrow opening at each discharge, and all the more, the more the condenser-action in the secondary circuit advances and the action of the self-induction recedes. If one extends the rays brought in from the side, analogous to the above, clear into the protruding layers of vapor surrounding the place of the spark, then one recognizes again that the rays with $n > 1$ point right into the heated path of the spark while those with $n < 1$ prevailingly point toward the outer electrode surfaces which are much cooled by the liquid. If spark-discharges are passed into gases at high pressure the diffusion of the metallic vapors is limited; denser refracting layers gather in the neighborhood of the path of discharge; hence phenomena similar to those with the spark under water may be expected here with sufficient increase of pressure in the surrounding gaseous atmosphere, provided always, that the absorption is sufficient, to which point attention has already been called. Hale's wonderful engravings prove this most completely. In all the cases named the distribution of brightness represented in fig. 4 must result in the neighborhood of the absorption line AA.

Fig. 4



With increasing absorption, indeed, the dark line AA can encroach more and more upon the domain of the brighter ones, so

that its middle seems to be shifted at first only a little and then not at all toward the violet, and eventually even slightly toward the red. With highly increased absorption, the bright lines corresponding to the rays in the vapor envelopes may even under some circumstances disappear altogether in the general background of light.

The great number of individual possibilities admitted by the principle of explanation here offered seems to me to be an essential advantage of the same rather than a disadvantage; yet the number of separate cases appearing with the different metals at the discharge under water or in high gas pressure is likewise enormous.

In its application to the phenomena of new stars the view here described gains an increased probability because it presents the direct completion and a necessary consequence of that theory concerning the phenomenon mentioned, which since then has proved itself most tenable in all other points, namely the Seeliger theory of the new stars.

H. von Seeliger assumes that with the flashing up of a new star a compact celestial body, in itself dark or only slightly glowing, travels with cosmic velocity into an extended cloud of dust which in itself glows but little or not at all. Almost daily celestial photography is teaching us that areas of cosmic dust or vapor are much more frequent in celestial space than was formerly suspected. On the other hand Nova Persei especially has demonstrated in the most evident way the close relation of the new stars to such nebulous formations. With the great relative speed between celestial bodies and particles of dust running against each other, the body must become greatly heated on the surface of its front side; but also the parts of the dust-cloud met and condensed by it must undergo a great increase of temperature, as Seeliger elsewhere has calculated for a few cases under perfectly plausible suppositions. With this heating there must be corresponding vaporization. Those substances will vaporize most quickly and most fully which have the lowest temperature of condensation, that is, helium and hydrogen. A thick covering of these must first accompany the body; metallic vapors are added later in rich measure. After this the phenomenon presents on a large scale in the realm of the fixed star system that which we observe on a small scale at the apparition of a meteor in the upper layers of our Earth's atmosphere. Here, too, then should be found spectral phenomena similar to those in the new stars, since the causes of the same—according to our theory the refraction of

light in the vaporous envelopes—are indeed different in degree but not in kind. Of course they are here incomparably harder to observer, and hence, so far as I know at least, have not yet been observed; the reason lies in the great swiftness of the apparition; while the new stars often show as bright shining objects in the heavens for a whole year's time, the duration of the brightest bolide or fire-ball is limited to seconds. Therefore, so long as chance does not bring a meteor of sufficient brilliancy over the plate of an astrospectrographic photograph, we must wait for the proof of this theory.

Let us trace the course of development of a Nova somewhat more closely: First, at the entrance of the body into the cosmic dust-cloud, a rather sudden light in the sky will inform us that this collision has taken place; this is, as Seeliger has already emphasized, vastly more probable than the collision of two celestial bodies against each other, or the collision of one such body with the members of another solar system. There would follow substantially at first only a continuous spectrum with the region of rays extending itself constantly farther into the ultra-violet.

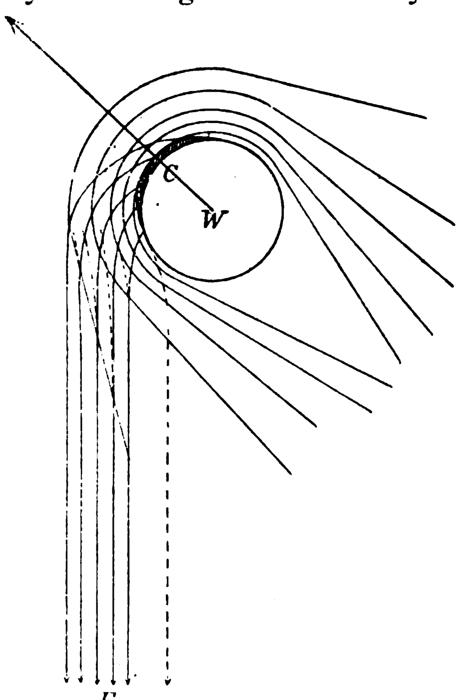


Fig. 5.

But very soon aërifications of the tiny particles must take place in the dust cloud; an absorbing vapor-covering extending itself more and more now surrounds the body, first, as shown above, of H_e and H_2, then of metals. We must imagine the arrangement of the same like that of the condensing waves about a round projectile flying with great velocity through the air, as they have frequently been illustrated by photographic instantaneous exposures by flashlight. In fig. 5 if W represents the body moving through the nebula in the direction of the arrow, then the maximum development of light will take place on the cap C, on the front side in the direc-

tion of the motion. Except in the very improbable case that the body is coming directly toward us, we shall see this brightest part C always more or less obliquely through the envelope of condensed gases and vapors. If then the Earth should chance to be in the direction E, the lines drawn in the figure will indicate the course of light which the spectral colors of the separate absorption lines of a certain element, for instance, that of hydrogen in the red, take. Even in case the observer is standing behind the star in the direction of any one of the stratum surfaces indicated in the figure there will still result a similar course of the rays. For a ray which we imagine to run from him to the star and to enter into the tangential surface separating two strata will be bent toward the direction of the increasing exponent of refraction, in this case inward. Inversely the rays emitted from the heated upper surface parts will reach the observer's eye by a corresponding deflection.

Quite different is the case for the higher vibrations, for which according to p. *242* the outer strata are optically the densest, while those situated nearer the centre have ever decreasing exponents of refraction. Rays of this kind which come from E must take about the course indicated by the dotted lines in the vaporous envelope; for them then the compact body W itself hides the greater part of the illumination developing on the front surface C. Even in case E lies much nearer in the direction of the motion of W than is supposed in the figure, the rays for which $n > 1$ will bring more light to the observer than the rays with $n < 1$. Therefore the absorption lines of those elements of which the envelope is mainly composed must seem in the spectrum to be very much spread out toward the violet (compare fig. 4); a dark shadow apparently stretches itself here over the continuous spectrum serving as a background for the whole; the middle of the line is shifted very strongly toward the violet. But toward the red there seems to be against the bright background a still brighter band whose intensity diminishes gradually toward the red and rapidly toward the violet, that is, toward the absorption line; the brightest edge of this band lies very near the normal place of the line with only a slight deviation toward the red. The brightness of this line may increase almost as rapidly as the dispersion curve itself, fig. 1. Another case may occur for these rays with an $n > 1$ in the strata of the vaporous envelope; this case is especially to be kept in mind and it is this; that the rays with highest n-value do not emerge at all but are entirely reflected. According to Seeliger this

happens with spherical celestial bodies when the height h of the atmosphere is

$$h > (n - 1)\ a$$

(a = radius) for the case when the atmospheric envelope of the variable refraction exponent n borders on a vacuum. Here then the brightness increases only to a certain maximum amount, which remains about the same for a large extent of wave-lengths; there appears a broad bright band of nearly equal intensity which borders sharply on the violet but gradually loses itself toward the red in the common brightness of the continuous spectrum. The centers of these bands are then shifted decidedly toward the red.

For all these cases sketched above, there are found, in the literature concerning the different Novæ, numerous examples which it would take too long to verify singly here.

Beside these diffuse, faded and greatly shifted bright and dark lines which we think of as arising in this way, there may also appear actual emission and absorption lines, sharply defined and narrow, which proceed partly from the gaseous envelope, partly from the celestial body itself. The velocities of movement derived according to the Doppler principle from these narrow and from the broad lines can never give identical values in general; for this too, numerous examples can be found in literature. An essential advantage of the Seeliger theory lies, aside from its great simplicity and naturalness, in the enormous wealth of individual possibilities which it admits. If the celestial body is coming toward us so that we have before it a comparatively thin layer of vapor, then the continuous spectrum and separate bright lines may dominate completely, the doubling of lines is only suggested. If it is moving away from us then we see it through layers of vapor constantly growing thicker, so that the line-shifting may increase to an extraordinary amount. Then a very sudden change may come in when masses of vapor escape and remain behind; there may even occur periodic brightenings such as we observe in our atmosphere at the appearances of meteors; simultaneous with these brightenings may be corresponding periodic changes in the spectrum.

But also through the different densities of cosmic dust-clouds, and variations of density in the same cloud, along the course in which the body passes it, and through the relative velocity of that body, arise new possibilities of individual phenomena. The points of relative maximum density of such a cloud will generally be found on a surface of doubled curvature, so that the body

may traverse several regions of increased density one after the other. Several of the spectral-phenomena are then successively awaiting us. In this way are easily explained the secondary maxima and minima of intensity which are occasionally superposed upon the broadened bright and dark lines in the spectra of the new stars; they are also obtained at the discharge of sparks in water, when one superposes the impression of separate sparks of different strength one upon another on a photographic plate. One needs only to draw the figure 4 once, twice or several times on different scales and to lay them one above another, at the same time simply adding the separate ordinates corresponding to the separate wave-lengths, in order to obtain all the different distributions of brightness with one, two or more relatively darker parts within the bright lines, and inversely bright lines in the dark parts; just as the spectrographs have many times revealed for Nova Aurigæ and Nova Persei. If the celestial body has left the dust-cloud, its brilliancy may decrease with great rapidity, comparatively speaking, if it be essentially only its surface which was heated by the collision with the dust particles, as here supposed; a phenomenon which is also very characteristic of the new stars.

Attention should still be called to one thing which supports this view from an entirely different side; the close connection of the new stars with nebulous patches, as has been discovered, for instance, in Nova Persei, and the corresponding strong relationship of the spectra of new stars with those of different nebulæ.

In a series of variable stars of short period, in whose spectra periodical shifts of the lines occur, the theory here set forth may find application. If the emission of light of a celestial body is essentially different on different parts of its surface, and if it is surrounded with a thick vapor atmosphere, then in its rotation it must offer to the distant observer a phenomenon changing in its development, of the kind described with its shifting and doubling of lines; the period of the same will then be that of its revolution on its axis. So we do not in this case require unconditionally the supposition of two celestial bodies one of which is moving toward us the other away from us.

In the mean time it must not be denied that in all the cases mentioned a role is actually played by shiftings of the lines which result partly from movements in the line of sight according to the Doppler principle, and partly from increase of pressure according to the well-known laboratory experiments in that matter. Through what has been said we wish to show chiefly that

besides motion and pressure the anomalous refractions are to be brought into consideration in the explanation of spectral phenomena of celestial objects.

MUNICH, September, 1903.

SPECTROSCOPE FOR SMALL TELESCOPE.

DAVID E. HADDEN.

FOR POPULAR ASTRONOMY.

During the past eight or ten years the writer has received numerous inquiries from amateur astronomical friends and correspondents for a suitable spectroscope, reasonable in price which could be used for viewing the solar prominences with a small telescope. These inquiries were prompted by the publication, a number of years ago, of a few articles descriptive of a home-made instrument which the writer used in his daily solar observations.

Since that time several desirable changes were made in the design, and a new one constructed which has been used with excellent results up to the present time.

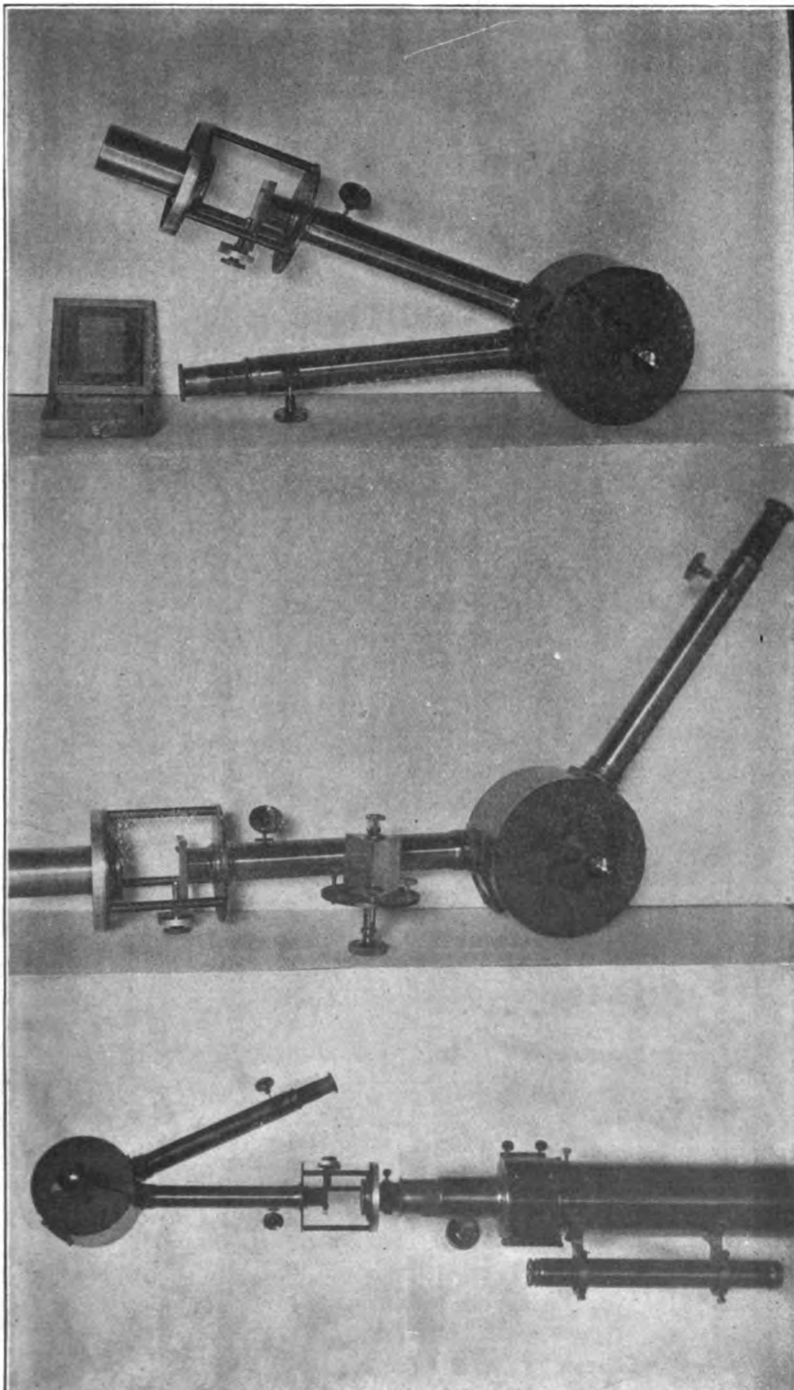
Quite recently, however, a desire to devote more attention to the spectroscopic investigation of the sunspots during the approaching maximum of solar activity, led me to procure a better instrument for this purpose.

Possessing an excellent 2-inch Rowland diffraction grating, which was obtained from Mr. Brashear a number of years ago, I designed the new instrument to accommodate it, and also a dense flint 60° prism.

The instrument was made by Wm. Gaertner and Co., of Chicago, and I am so well pleased with its workmanship, reasonable price and performance, that a description of it may be interesting to the readers of POPULAR ASTRONOMY.

Figure 1 shows the appearance of the instrument used as a grating spectroscope, the observing telescope and collimator each have lenses of one inch diameter and seven and one-half inches focus, with rack and pinion adjustment for eyepiece and slit plate; the latter has German silver sliding plates, with a small micrometer head for measuring the width of slit and determining the height of prominences; the eyepiece tube is supplied with crossed hairs and ½ inch and ⅞ inch eyepieces.

At the end of the collimator tube is firmly fastened a round disc of brass 3 inches in diameter, connected with a similar disc by



three round brass bars 3 inches long and ¼ inch diameter; closely connected with the latter disc is a silvered position angle circle, reading to single degrees; this disc is firmly secured to a short piece of tubing 1¼ inches diameter which can be inserted in the eyepiece tube of the 4-inch telescope or 8½-inch reflector, retained by means of a small clamp, and the entire instrument is securely fastened and all danger of slipping off is prevented. The spectroscope can now be rotated easily at the junction of the disc and position circle and the angle of position of a prominence determined.

The grating table is rotated by hand, but the writer has inserted a couple of geared wheels and by means of a thumb screw nut near the circumference of the grating box, the grating can be easily and smoothly rotated without removing the cover of the box.

Figure 2 indicates the appearance of the instrument when used as a prismatic spectroscope for chemical or stellar work. For this purpose the grating is removed and the small table containing the prism, inserted in its stead, the observing telescope is unscrewed, and screwed into an opening at the proper angle on the side of the grating box, and the openings in either case closed by means of a small cap to exclude all extraneous light.

Figure 3 gives a view of the spectroscope attached to the 4-inch Brashear refractor, and adjusted for viewing the solar prominences or examining spot spectra with the grating. The instrument is brass, light in weight, yet strongly made, and is finished in dull black with tubes polished and lacquered.

ALTA, Iowa.
Feb. 15th, 1904.

ANNA WINLOCK.

MARY E. BYRD.

FOR POPULAR ASTRONOMY.

Anna Winlock was born in Cambridge, Massachusetts, September 15, 1857. The eldest child of Joseph and Isabella Lane Winlock, she had the happy birthright of distinguished ancestry. On the side of both father and mother her lineage is traced back to old Virginia families that helped to win American independence, and later to found the new states of Kentucky and Missouri.

Her father, though his life was short, connected the family name indelibly with astronomy, and Anna Winlock as a child had her home in Harvard College Observatory. It was also under astronomical auspices, at the time of the total solar eclipse of 1869, that her first visit was made to the old home in Kentucky.

She was educated in the Cambridge schools, showing quite early a taste for mathematics, and in the high school excelling in Greek. It was not a common thing in those days for young girls to study Greek and at the time of graduation she received a letter from the principal expressing in the warmest terms his appreciation of her Greek and of her character. Two months later, a young girl in her teens, with no training beyond that of the high school, she took up, in a humble way, her father's work, cut short by his sudden death in June, 1875.

The largest and finest instrument which he had added to the equipment, while director of Harvard College Observatory, was the meridian circle, made by Troughton and Simms, of London, from specifications which included a number of improvements suggested by himself. This instrument was mounted and ready for use in the latter part of 1870, and its possession made it possible for the observatory at Cambridge to join with a number of foreign observatories in a comprehensive scheme for preparing a great star catalogue which should give accurate places of most of the stars in the northern heavens from the first to the ninth magnitudes inclusive. The portion of the sky to be observed for the catalogue was divided into fourteen sections or zones by circles parallel to the celestial equator. A beginning was made promptly on the Cambridge zone, which extended from the 50th to the 55th parallel of north declination. Observations and reductions were placed under the immediate charge of the astronomer, William A. Rogers; and the director, Mr. Winlock, lived to see five years of the work accomplished.

It was in connection with these meridian circle observations that Miss Winlock's first computing was done at Harvard College Observatory. With the first entry of her name in the record books, appear the brief headings, "Copying observations," "Taking means." She began work on the Cambridge zone as a school girl, before it was finished, she was furthering its progress as an astronomer.

Perhaps it is fortunate that in the early years she could not realize how long and arduous was the undertaking to which she had set her hand. The Cambridge zone was among the first to

be published, but it bears the date of 1891, and it was not until five years later that the last supplementing volume appeared. In the catalogue proper there are 8627 stars, and of these more than 26,000 observations were taken, each one including transits for right ascension and declination as well as the reading of microscopes.

The mere routine part of the computing is appalling. To read the chronograph record for one evening required about the same time as to take the observations themselves, and then the reduction was hardly begun. On one page of one of the seven volumes of the Annals of Harvard College Observatory, devoted to this zone, there are more than three thousand figures, in the volume, more than 290 pages of figures so that the whole number counts up to hundreds of thousands. All in all the published figures must be reckoned in millions and for each figure in print there are doubtless ten or twenty back of it upon which it depends for its value, each and every one of which demanded care and thought. And after all else was done there remained the laborious task of checking: for star places must be about as trustworthy as logarithms.

Accuracy in simple calculations lies at the foundation of success in reducing astronomical observations but a far higher type of ability is required to comprehend observations and reductions as a whole, to understand the connection between note-book records and chronograph sheets and the pertinent precepts of theoretical astronomy, and to adapt and apply mathematical formulæ to attain the ends sought. This ability Miss Winlock evinced early, and it was joined to a power for conscientious, persistent work still more rare. During the many years in which the Cambridge zone was in process of preparation, Mr. Rogers had help from five or six assistants. Their periods of labor were some shorter, some longer; but one by one they dropped off. Even he himself had severed his official connection with Harvard College Observatory, before the printing was completed. But Miss Winlock worked on and on, for more than twenty years, developing no small power as a mathematical astronomer, and taking an ever increasing share of responsibility till in the end Mr. Rogers regarded her not so much an assistant as a co-worker. Well had she earned that recognition; and the work of her patient years is builded for all time into the catalogue of the Astronomischen Gesellschaft, of which the Cambridge zone is an integral part. All the zones combined give a catalogue of more than a hundred thousand stars, containing fundamental data for a large part of

the work of precision in astronomy, honored by constant use in large and small observatories by a great body of investigators.

While Miss Winlock's devotion to this catalogue was almost co-extensive with her life, what she thus accomplished was by no means her only contribution to astronomy. Before the last volume of the journal of the zone was published, she was aiding in other researches of the observatory. Under her supervision a table was prepared for volume XXXVIII of the Annals which contains the positions of variables in clusters and of their comparison stars. For Eros, the asteroid of special significance, offering as it does one of the keys to solar parallax, she made lengthy calculations in order to predict its path for future years and thus further its observation at the opposition of 1903. She computed a circular orbit for the asteroid Ocllo, discovered at Harvard's southern station, Arequipa, Peru, and later assisted Dr. Newcomb in determining its elliptical elements which brought out the interesting fact that of all asteroids, its path about the Sun deviates most widely from a circle.

Miss Winlock's most important, independent investigations are to be found, perhaps, in the four memoirs connected with her name. Taken together they constitute the most complete catalogue of stars near the north and south poles, so far attempted. Parts 9 and 10 of volume XVIII of the Annals are based upon the meridian circle, and include all the observations, taken with it or like instruments, of 52 stars within one degree of the north pole, and of 26 stars within two degrees of the south pole, respectively. Part 9 treats of the method of Fabritius to be employed, and gives the table especially prepared for precession and secular variation of co-ordinates which are used in both parts. The materials were gathered from scores of different authorities, distributed over a century and a half, discussed and marshaled so as to present in convenient form not only the position and proper motions deduced, but also all the data for these results given by the old astronomy. The other two parts of what may be called this general polar catalogue contain a much larger number of stars and depend upon photographs of regions about the poles. The last one, dealing with the south pole, has not yet been published. It was her last astronomical work.

As to her father and brother, death came suddenly to Anna Winlock. Toward the close of last year, she was not quite so well as usual, being troubled with a cold. She gave little thought to it, however, going on with her varied duties at home and at the observatory, writing letters to friends and sending

away tokens of Christmas remembrance. On December 17, though she little realized it, she went up to Harvard College Observatory for the last time. Her record there of more than twenty-eight years was closed. Still she worked on a little longer. The last entry in her current note-book of reductions is December 28, and on New Year's day she had notes on the "south polar catalogue" and other astronomical papers beside her on the bed. Her death came three days later, and in St. John's chapel, endeared to her by family associations and many years of worship, less than two weeks after her last attendance there, her funeral service was held.

To friends and kindred she leaves a rich legacy simply by having lived. Her delicate sense of humor gave a very human touch to a nature too spiritual and too intellectual to be understood by all. Her gentle loving kindness veiled in part the power of her intellect. Doubtless many knew her without realizing how far beyond the average were her powers of mind. She seemed not to realize it herself. For a little thing that others did she was prodigal with hearty praise while she quietly, but persistently ignored real achievements of her own.

Most of the lines in the sonnet to Joseph Winlock, by James Russell Lowell, are as true of the daughter as of the father. She too was,

> "Careless of fames that Earth's tin trumpets fill"
> Strong of soul and "patient of Will" she labored
> "Through years one hair's breadth on our
> Dark to gain."

VARIABILITY OF IRIS (7).

EDWARD C. PICKERING.

A series of measurements of the light of the planet Iris (7) has been made by Professor Wendell with the polarizing photometer, with sliding achromatic prisms, attached to the 15-inch equatorial telescope of the Harvard College Observatory. A variation like that of the planet Eros has been established, having a period of about $0^d.259 = 6^h\ 13^m$. The range is only two or three tenths of a magnitude, and the variation would be uncertain but for the very small accidental errors which occur in observations made in this way. See Circulars Nos. 23, 25, 30 and 41.

The results of the measures made by Professor Wendell are given in Table I. The Julian Day and fraction following Green-

wich Mean Noon, omitting the three left hand figures, 241, is given in the first column. The designation of the comparison star is given in the second column. The observed difference in magnitude between Iris and the comparison star is given in the third column, a positive sign indicating that the star was brighter than Iris. The fourth column gives the phase computed by the formula 2,416,470^d.000 + 0^d.259 E. The fifth column gives the amount that Iris is fainter than its assumed maximum magnitude. This quantity was found by plotting the times and observed differences in magnitude on each night, and by inspection assuming the maximum magnitude. The latter was then subtracted from the observed magnitude, and a curve constructed from these differences and the corresponding phases. Owing to errors in the assumed maximum magnitudes, the points on some nights were above and on others below the curve. The mean value of the deviations from the curve for each night was therefore subtracted from these differences and gives the quantity contained in the fifth column. Negative signs are indicated by italics. This process was necessary, since different stars were used on different nights, and we had no means of knowing their true magnitudes. The sixth column gives the residual found by subtracting the magnitude as given by a smooth curve from that contained in the fifth column. The average value of these 46 residuals is only ± 0.022.

TABLE I.

OBSERVATIONS OF IRIS (7).

J. D.	DM. °	Diff.	Phase.	M.	O—C.
6475.606	+ 18 1576	— 0.79	0.167	0.22	0.03
" .612	" "	0.86	0.173	0.15	*0.02*
" .658	" "	1.01	0.219	0.00	*0.01*
" .665	" "	1.02	0.226	*0.01*	*0.02*
6477.645	+ 18 1553	0.96	0.134	0.06	*0.02*
" .651	" "	0.90	0.140	0.12	0.02
" .662	" "	0.86	0.151	0.16	0.00
6479.603	+ 18 1538	+ 0.12	0.020	0.21	0.02
" .611	" "	+ 0.11	0.028	0.20	*0.01*
" .656	" "	— 0.02	0.073	0.07	0.04
" .664	" "	0.07	0.081	0.02	0.00
6480.552	" "	0.08	0.192	0.05	*0.02*
" .558	" "	0.13	0.198	0.00	*0.04*
" .586	" "	0.07	0.226	0.06	.05
" .612	" "	0.07	0.252	0.06	*0.01*
" .621	" "	0.04	0.002	0.09	*0.03*
6485.565	+ 18 1496	1.66	0.025	0.25	0.04
" .570	" "	1.68	0.030	0.23	0.02
" .601	" "	1.83	0.061	0.08	0.00
" .606	" "	1.91	0.066	0.00	*0.04*
" .624	" "	1.88	0.084	0.03	0.01
" .631	" "	1.90	0.091	0.01	*0.01*
" .651	+ " "	— 1.86	0.111	0.05	0.00

Table I.—Continued.

Observations of Iris (7).

J. D.	DM.	Diff.	Phase.	M.	O—C.
6485.660	+ 18 1496	— 1.83	0.120	0.08	0.02
6487.540	+ 18 1495	1.68	0.187	0.10	0.00
" .546	" "	1.72	0.193	0.06	0.00
" .568	" "	1.76	0.215	0.02	0.01
" .576	" "	1.76	0.223	0.02	0.01
" .599	" "	1.73	0.246	0.05	0.00
" .606	" "	1.75	0.253	0.03	*0.04*
" .627	" "	1.64	0.015	0.14	*0.04*
" .636	" "	1.59	0.024	0.19	*0.02*
" .656	" "	1.68	0.044	0.10	*0.03*
" .664	" "	1.71	0.052	0.07	*0.01*
5495.567	+ 18 1419	1.00	0.185	...	...
" .574	" "	1.02	0.192	...	...
6498.543	+ 18 1391	1.99	0.053	0.08	0.00
" .551	" "	2.04	0.061	0.03	*0.02*
6499.524	" "	1.82	0.257	0.21	0.10
" .530	" "	1.82	0.004	0.21	0.07
" .546	" "	1.80	0.020	0.23	0.03
" .552	" "	1.82	0.026	0.21	0.00
" .578	" "	1.96	0.052	0.07	*0.01*
" .585	" "	1.97	0.059	0.06	0.00
" .603	" "	2.01	0.077	0.02	0.00
" .610	" "	2.08	0.084	*0.05*	*0.07*
" .630	" "	2.03	0.104	0.00	*0.03*
" .660	+ 18 1391	— 1.96	0.134	0.07	*0.03*

Table II.—Light Curve.

Ph.	M.	Ph.	M.	Diff.
0.00	0.12	0.13	0.09	0.03
0.01	0.16	0.14	0.12	0.04
0.02	0.19	0.15	0.17	0.02
0.03	0.21	0.16	0.19	0.02
0.04	0.17	0.17	0.18	*0.01*
0.05	0.10	0.18	0.14	*0.04*
0.06	0.05	0.19	0.09	*0.04*
0.07	0.03	0.20	0.06	*0.03*
0.08	0.02	0.21	0.02	0.00
0.09	0.02	0.22	0.01	0.01
0.10	0.03	0.23	0.02	0.01
0.11	0.04	0.24	0.03	0.01
0.12	0.06	0.25	0.03	0.03

The cöordinates of the light curve are given in Table II. The phases are given in the first and third columns, the corresponding magnitudes in the second and fourth columns. The differences found by subtracting the numbers in the fourth column from those in the second are given in the fifth column. It will be seen therefore that there are two maxima and two minima, which are so nearly equal that it is as yet impossible to say whether the differences are real or due to small systematic errors. In the latter case, the period should be divided by two, and become $0^d.1295 = 3^h\ 6^m$.

It will be seen that the variation closely resembles that of Eros, and that the conditions discussed in Circular No. 58, apply to

Iris also. The latter asteroid is bright enough to be readily observed during a large part of the time, but unfortunately the change of light is now so small that it can be determined only by observations in which the accidental errors are extremely small. In fact, the observations of Iris made at Potsdam in 1884 (Publicationen, VIII, 294) fail to show this variation, either because the range was then too small, the period was then different, or the errors of observation rendered the variation imperceptible. The average of the residuals on the twenty-six nights of observation was ± 0.073, or about the same as that for the other asteroids. A change in the period seems improbable.

The observations contained in Table III were made on January 25, 1904, after the above discussion was completed. Iris was compared with + 17° 1404, and the Julian Day and fraction, difference in magnitude, and phase, are given in the successive columns. It will be seen by plotting these observations, that they fall almost exactly upon a smooth curve and that the phase of maximum, $0^d.085$, agrees very nearly with that derived from the previous observations. A change, however, appears to have taken place in the range which now exceeds three-tenths of a magnitude, or an increase of about one-half in a few days. This change is confirmed by the last ten residuals in the last column of Table I, which indicate that the increase in range occurred between J. D. 6487 and J. D. 6499. The change in the range of Eros in the spring of 1901 was also much more rapid than might have been expected from geometrical considerations. The range on March 12, 1901, was found to be about 1.0, on April 12, 1901, 0.4, and on May 6 and 7, 1901, 0.0, magnitudes.

TABLE III.

LATER OBSERVATIONS.

J. D.	Diff.	Ph.
6505.539	— 0.52	0.056
" .546	0.56	0.063
" .562	0.59	0 079
" .569	0.60	0.086
" .585	0.58	0.102
" .592	0.56	0.109
" .610	0.44	0.127
" .619	0.37	0.136
" .636	0.28	0.153
" .645	0.34	0.162
" .656	0.38	0.173
6505.662	— 0.46	0.179

Evidently, this object should be watched carefully. It is now favorably situated, as it is approaching its second stationary point, and is of about the eighth magnitude. Iris can be con-

veniently compared photometrically with the stars + 17° 1339, + 17° 1355, + 17° 1364, and + 17° 1391, during the next few weeks, and it is hoped that observers elsewhere will connect their observations with these stars and with the comparison stars used in Tables I and III, so that all may be reduced to one system. Measures of the absolute magnitudes of these stars will be undertaken here. It will be noticed that observations on each night should extend over at least three hours. In that case, a maximum and minimum will always be included, so that the absolute magnitudes of the comparison stars will be of less importance.—From *Harvard College Observatory, Circular No. 75.*

January 27, 1904.

CHARLES HALL ROCKWELL.

W. W. PAYNE.

We have waited longer than previously planned to pay a deserved tribute, in this publication, to the memory of our long known and esteemed friend, the late Charles H. Rockwell. His relatives and many friends will kindly overlook this in us, when we say that it seemed fitting to wait unusually and unexpectedly long for the engraver to do his work well, that all who read the mute words of these pages might once more look on the familiar features of that expressive face, that holds us all, now, heart to heart in thoughtful mood, as a cherished friend has bidden his adieu, and closed on Earth a happy and a most useful life.

Charles H. Rockwell was born at Hartford, Conn., July 17, 1826, and died at Tarrytown, N. Y., Jan. 1, 1904. His youth was spent at Norwich in the same state. In 1843 he entered the laboratory of Professor Benjamin Silliman of Yale College for instruction in chemistry. It is noteworthy that young Rockwell chose one of the best places, if not the very best, for instruction in this important branch of study at that time.

Professor Silliman was then an authority in chemistry, and was also the founder of a very strong journal in that science which has borne his name from that day to this. At that time he made the acquaintance of A. D. Stanley, Professor of Mathematics, who directed his attention to the application of mathematics to astronomical work, and thus determined the bent of his mind that afterwards controlled so large a part of Mr. Rockwell's life.

In 1850 he made a voyage to California around Cape Horn,

and by this means, received instruction in navigation and became skillful in the use of the sextant. While in California and residing at San Francisco, he improved the opportunity in making frequent visits to the Observatory of the Coast Survey, located at that place, to gain information about the use of astronomical instruments.

Later his marriage, the loss of his wife and child, and his services during the Civil War brought him to the year 1866. In 1869 he established himself at Tarrytown, New York, and at that place he built a small astronomical observatory, and entered on the work of an amateur astronomer, which calling seemed to be the delight of his life, and the wide circle of scientific friends it made for him were highly prized and worthily kept during his life.

He procured only the best astronomical instruments for his own Observatory, in the latest and most approved patterns considering the size adapted to the work for which they were to be used. As an instance of this we call to mind his lively interest in Professor S. C. Chandler's new instrument, devised years ago, which goes by the name of the Almucantar. Mr. Rockwell quickly saw the superior advantages of it, and was the first, if we remember rightly, to place an orde r for it for his Observatory.

Outside of his own Observatory, the total solar eclipse was one of the most absorbing themes in practical astronomy that engaged Mr. Rockwell's attention. He was often found in the expeditions of prominent astronomers in the United States, or, in planning and conducting those of his own to remote parts of this country. A single incident will serve to illustrate his interest in, and close attention to, these rare opportunities for the study of unknown and very difficult solar phenomena. The prediction for the total solar eclipse of 1883, gave a portion of the path of totality in the south Pacific Ocean. Because the narrow band of shadow crossed no prominent islands, little attention was given to it. As the time of the eclipse was approaching, Mr. Rockwell examined its path carefully, and was the first, in this country, to notice that it would pass over that insignificant, rock reef, nine miles long by one mile wide, known by the name of Caroline Island, at a favorable time for observation. This fact he made known to astronomers, and as a result, an expedition of experienced observers including Mr. Rockwell was formed and, on May 6, 1883, the desired observations were successfully made. New information concerning the solar corona, was the chief feature of this expedition.

Other similar expeditions in which Mr. Rockwell had a part were the solar eclipse of 1878, Colorado; 1881, Transit of Mercury, Honolulu; 1889, solar eclipse, California, and 1889, the solar eclipse, Cayenne, South America. The last named expedition was from Lick Observatory, and Mr. Rockwell assisted in the photographic work. It was reported that all the plates turned out well. The curved rays of the corona came out beautifully on some of the plates, which was a thing of special interest as mentioned by Mr. Rockwell in a private letter to the editor of the *Sidereal Messenger* extracts from which were published in that magazine, Vol. IX. 1890, p. 94.

An expedition to the Hudson's Bay Company's station at Moose Factory in the summer of 1880 is worthy of mention. A party was formed comprising Dr. George W. Hill, Lieut. S. W. Very of the Navy and Mr. Rockwell, and starting from Lake Superior it followed the well known trade route up the Michipicotton River and down the Moose River to Hudson's Bay and returned by the same route. Lieut. Very was the astronomer of the party, Dr. Hill the topographer and Mr. Rockwell the quarter master and general director. Good observations for latitude and longitude were made both going and coming, and Dr. Hill has embodied the results in an excellent map which remains in manuscript in his hands awaiting the appearance of some public spirited friend who will provide funds for its publication.

We have already spoken briefly of Mr. Rockwell's interest in the new instrument devised by Professor S. C. Chandler, known as the Almucantar. At the Minneapolis meeting of the American Association for the Advancement of Science, in 1880, Professor Chandler presented a paper showing the construction of the instrument and the methods of its use. The paper was published in Vol. 2 of the *Sidereal Messenger*, p. 269. In that paper reference was made to some results obtained by the new instrument in the determination of latitude that were surprisingly accurate for one so small as that which was used. It readily detected errors that seemed to have been troublesome with larger and more expensive instruments. In that paper only the merest reference was made to its use in determining time, although its effectiveness might be inferred from the precise results obtained in latitude work. In Vol. 3 of the *Sidereal Messenger*, page 285, will be found a reference to Mr. Rockwell's work with the Almucantar. The results of his observations for time are there given, and they are for four consecutive days remarkably close, the pairs of stars varying only in hundredths of seconds of time.

PLATE IX

CHARLES HALL ROCKWELL

1826-1904

In his latitude work Mr. Rockwell's attention was called to a discrepancy in the results obtained from the same stars, after an interval of three years. He communicated the fact to Professor Chandler who found in his observations material to aid in detecting the complex motion of the geographical pole of the Earth, which has occupied the attention of astronomers so much during the last few years, and in which Professor Chandler has been a brilliant leader in the mathematical and theoretical investigation of this difficult problem.

In the pursuit of an accurate time-piece Mr. Rockwell devised a pendulum which he believed had points of excellence that he desired to test thoroughly. About the same time his friend, J. H. Gerry, of Brooklyn, N. Y., had thought out another, and invited a contest between the two. To this end Mr. Gerry constructed two clocks, as nearly identical as he could make them, and attached one of the rival pendulums to each and they were started in competition. In August 1898, a few months later, Mr. Rockwell had an attack of paralysis which rendered him incapable of continuing the work, and it was taken up and carried to completion by his brother.

Apart from that portion of his life which was more or less of public interest, Mr. Rockwell's life was filled with private benefactions that endeared him to a host of friends. Among these that have had a wide influence in science and public life is the assistance rendered to J. E. Keeler, that brought him, a boy in obscure life on the sands of Florida, and started him on a career that placed him, when in his prime of life among the most noted of astronomers in the world. Some of Mr. Rockwell's friends have well said, if he had only done this one good deed in his life, it would entitle him to a place on the roll of fame.

Mr. Rockwell's life was many sided; he was at home among sportsmen, travelers, geographers, sailors and astronomers, and popular with them all.

TRAILS OF STARS NEAR THE NORTH POLE.

W. W. PAYNE.

The frontispiece to this number of POPULAR ASTRONOMY is a reproduction of a photograph taken by Dr. H. C. Wilson in December, 1903, by the aid of the Brashear 6-inch camera which is attached to the 8¼-inch equatorial of Goodsell Observatory for the sake of the driving apparatus connected with that telescope

for ordinary work. In this particular photograph no clock-work was needed, as most readers will readily understand when it is stated that the central part of the picture represents the position of the north celestial Pole of the heavens.

To get the effect shown in this picture, the photographic camera was carefully pointed to the pole and permitted to remain undisturbed for the length of exposure desired. In this instance, the exposure began at 6 o'clock in the evening, and it was continued until 6 o'clock the next morning. If the reader will notice carefully, the trails of the brightest stars are beautifully continuous in width throughout the twelve hours until near the end, at which place they are broken up into dots and dashes, some of the latter of which are sharply pointed in the original negative. The meaning of the broken curves at the end is that clouds interfered with the exposure near the last of it.

It is also noticeable that there are very faint stars quite near the Pole as their trails appear as very small semi-circles around the middle point of the figure. The bright trail three-fourths of an inch from the center is the path of Polaris, and the strong trails further away are the bright stars of the Great Dipper. The picture is an interesting one for the number of star trails shown and also for the length of uninterrnpted exposure given to it. In this latitude it would not be possible to expose this region of the sky in one night more than fourteen hours. It is deemed a rare opportunity to get twelve good consecutive hours for photographic work in any one night during any time of the year.

Another interesting thing which Dr. Wilson hoped to bring out by this long exposure, was the detection of variable stars, if such there were in this region. It will be readily understood that if any star trail on the plate should show a broadening or narrowing in any part that would suggest rapid variation and lead to careful study of such stars to learn certainly if they were or were not variable stars. We have not found variation in the trails as far as examined. The exposure of this region for twelve hours, is one of the longest, if not the longest, as far as we know.

THE NUMBER OF THE STARS.

GAVIN J. BURNS, B. Sc.

FOR POPULAR ASTRONOMY.

Various estimates of the number of stars of each magnitude have been made by astronomers. One of these estimates will be found on p. 506 of vol. IX of POPULAR ASTRONOMY. But, till recently, owing to the lack of trustworthy data, all such estimates have been very rough. The progress that has been made in recent years in stellar photometry, and the work lately done in the preparation of the Astrographic Chart enable us to form a better idea of the number of the stars than has hitherto been possible.

The Harvard Photometrics give a complete list of all stars down to the sixth magnitude. According to those photometrics, there are

38	stars	under	magnitude	2
99	"	from	"	2 to 2.99
317	"	"	"	3 " 3.99
1020	"	"	"	4 " 4.99
2865	"	"	"	5 " 5.99

There is at present no complete list of stars from magnitude 6 to 6.99. The Harvard Photometric Durchmusterung contains all stars to magnitude 7.5 and within 130° of the N. pole. The number of stars from 6 to 6.99 given in this catalogue is 7848 according to W. Gore, from which he estimates the number for the whole sphere at 9554, by assuming them to be uniformly distributed.* I believe a somewhat better estimate can be obtained in the following manner. The number of stars in the H. P. D. brighter than the 6th magnitude is 3749, while the total number, according to the Harvard Photometrics, is 4339. Then, assuming a uniform ratio of stars under the sixth magnitude to stars under the seventh magnitude, we get the following proportion:

$$3749 : 4339 :: 7848 : 9082.$$

This will give a total of stars brighter than the seventh magnitude of 13421, (say 13,400).

For stars from the seventh to the ninth magnitude, we have to base our estimate on the Bonn Durchmusterung. The number of stars under the seventh magnitude in the Northern hemisphere is 5876 according to the B. D., whereas the total, as we have

* *Journal of British Astronomical Association*, XII. 128.

seen, is about 13400. By assuming that the ratio is the same for stars of fainter magnitudes, we get the following figures:

	No. of stars in B. D.	Estimated total.
Under mag. 7	5,876	13,400
" " 8	19,699	45,000
" " 9	77.794*	177,000

It is here assumed that the scale of magnitude in the B. D. is the same as the photometric scale. As the H. P. D. gives the magnitudes of many stars of the 8th and 9th magnitude, a comparison can be made between the scales. An examination of the magnitudes of such stars shows that, although in individual cases, the magnitudes differ widely, yet, on an average, the two scales are nearly the same.

With respect to stars fainter than the 9th magnitude, our knowledge is very indefinite. The most recent information is contained in a paper giving "Statistics of stars in a zone of 5° from + 65° to + 70° decl. counted on photographs for the Astrographic Chart and Catalogue at the Royal Observatory, Greenwich."† This paper gives an enumeration of 229426 stars. The following is a summary of the results:

No. in B. D. of 9th mag. and brighter	3094
No. shown on photographs in duplicate with an exposure of 20^s	6663
No. shown on photographs in duplicate with an exposure of 3^m	38262
No. shown on photographs in duplicate with an exposure of 40^m	199776

The above figures all refer to the zone mentioned above.

"On the assumption that an equal total amount of light produces an equal photographic effect, an additional magnitude is reached by increasing the exposure 2.5 times. Between the 3^m and 20^s (ratio 9 to 1) there corresponds a difference of magnitude of 2.38. Between the 40^m and 20^s exposure (ratio 120 to 1) there is a difference of 5.20. If r be the ratio of the number of stars down to magnitude $m + 1$ to the number down to magnitude m, we obtain

$$\left.\begin{array}{l} r^{2.38} = 4.29 \text{ from the } 20^s \text{ and } 3^m \text{ images.} \\ r^{5.20} = 29.58 \text{ from the } 20^s \text{ and } 40^m \text{ images.} \end{array}\right\}$$

$$\left.\begin{array}{l} \text{Thus from the } 20^s \text{ and } 3^m \text{ images, we get } r = 1.84 \\ \text{and from the } 20^s \text{ and } 40^m \text{ images, we get } r = 1.92\text{''} \end{array}\right\}$$

* From a table given by J. J. Plummer, in *Monthly Notices*, XXXVII, 436.

† *Monthly Notices*, Jan. 1903.

The zone on which these values of r are based is about 1/60th of the whole sky. Probably the average value of r does not differ much from the values above found. Assuming $r = 1.9$, and the number of stars under the 9th magnitude = 177000, we get the following figures:

Total number of stars under mag.	9	177,000
" " " " "	10	336,000
" " " " "	11	639,000
" " " " "	12	1,214,000
" " " " "	13	2,306,000
" " " " "	14	4,382,000
" " " " "	15	8,325,000

The following table gives a summary of the results:

Magnitude.	Number.	Total.	r
Under 2	38	—	—
2 and under 3	99	137	3.6
3 " " 4	317	454	3.3
4 " " 5	1,025	1,474	3.2
5 " " 6	2,865	4,339	2.9
6 " " 7	9,082	13,421	3.1
7 " " 8	31,579	45,000	3.4
8 " " 9	132,000	177,000	3.9
9 " " 10	159,000	336,000	1.9
10 " " 11	303,000	639,000	1.9
11 " " 12	575,000	1,214,000	1.9
12 " " 13	1,092,000	2,306,000	1.9
13 " " 14	2,076,000	4,382,000	1.9
14 " " 15	3,943,000	8,325,000	1.9

The numbers in the last column are the ratios of the successive totals. It will be noted that there is a sudden drop in the value of this ratio at the 10th magnitude. It might be supposed that this is due to the change in the method of determining magnitudes, which have been ascertained by eye observations from magnitudes 1 to 9, and by photography from 10 to 15. Some visual observations of my own, however, are quite in accordance with the figures given in the table. As the result of 122 gaugings taken in various parts of the sky, I found that the number of stars visible with a ¾-inch aperture, and the number visible with a 3-inch aperture is nearly in the ratio 3.40. Now, a ratio of 1.4 in aperture represents just 3 magnitudes, and a ¾-inch aperture shows stars to the 8th magnitude or somewhat fainter. The ratio shown in the table for magnitudes 8 and 11 is 3.42. The closeness of this agreement shows that there is a real drop in the value of r at about the 10th magnitude, and that it is not due to errors of observation.

Assuming that the stars are uniformly distributed throughout space, it may be readily shown that $r = 4$. The fact that r is always less than 4, and that its value diminishes for the fainter

magnitudes, is strong presumptive evidence that the stars thin out as their distance from our system increases.

ON THE SIX YEARS' CYCLE OF THE POLAR MOTION DURING THE INTERVAL 1891-1902.*

H. KIMURA.

During the study of the polar motion, I have found that the returns of the same phases (not the amplitudes) in the motion of the pole at the same epochs of the year during the interval 1890-1902 take place in six years. This interesting fact is seen at a glance on the accompanying diagram, in which the values of the two components, x and y, are taken from those given by Professor Albrecht, those for the epochs before 1899.8 being corrected throughout by the same ξ given in my paper A. N. 3783. The diagram also shows that the maximum deviations of the instantaneous pole occurred in 1891 and 1897, and the minimum, in 1894 and 1900. Thus it might be inferred that the next maximum and minimum will come in 1903 and 1906 respectively.

If we assume the existence of a certain principal annual term in the polar motion, the above fact indicates that the other term will have a period of 438 days. Under this consideration, I have found, by successive approximations, the following expressions of x and y for the two epochs:

I. Epoch, 1890.0-1896.0.

$$x = -0''.145 \cos\left((t - 1894.73) \times 300^\circ\right) + 0''.014 \sin \odot - 0''.130 \cos \odot$$

$$y = +0''.145 \sin\left((t - 1894.73) \times 300^\circ\right) + 0''.070 \sin \odot + 0''.027 \cos \odot$$

II. Epoch, 1896.0-1902.0.

$$x = -0''.145 \cos\left((t - 1894.73) \times 300^\circ\right) + 0''.013 \sin \odot - 0''.085 \cos \odot + 0''.008$$

$$y = +0''.145 \sin\left((t - 1894.73) \times 300^\circ\right) + 0''.051 \sin \odot + 0''.002 \cos \odot + 0''.009$$

where t is expressed in the units of a year, and $\odot$ is the longitude of the Sun.

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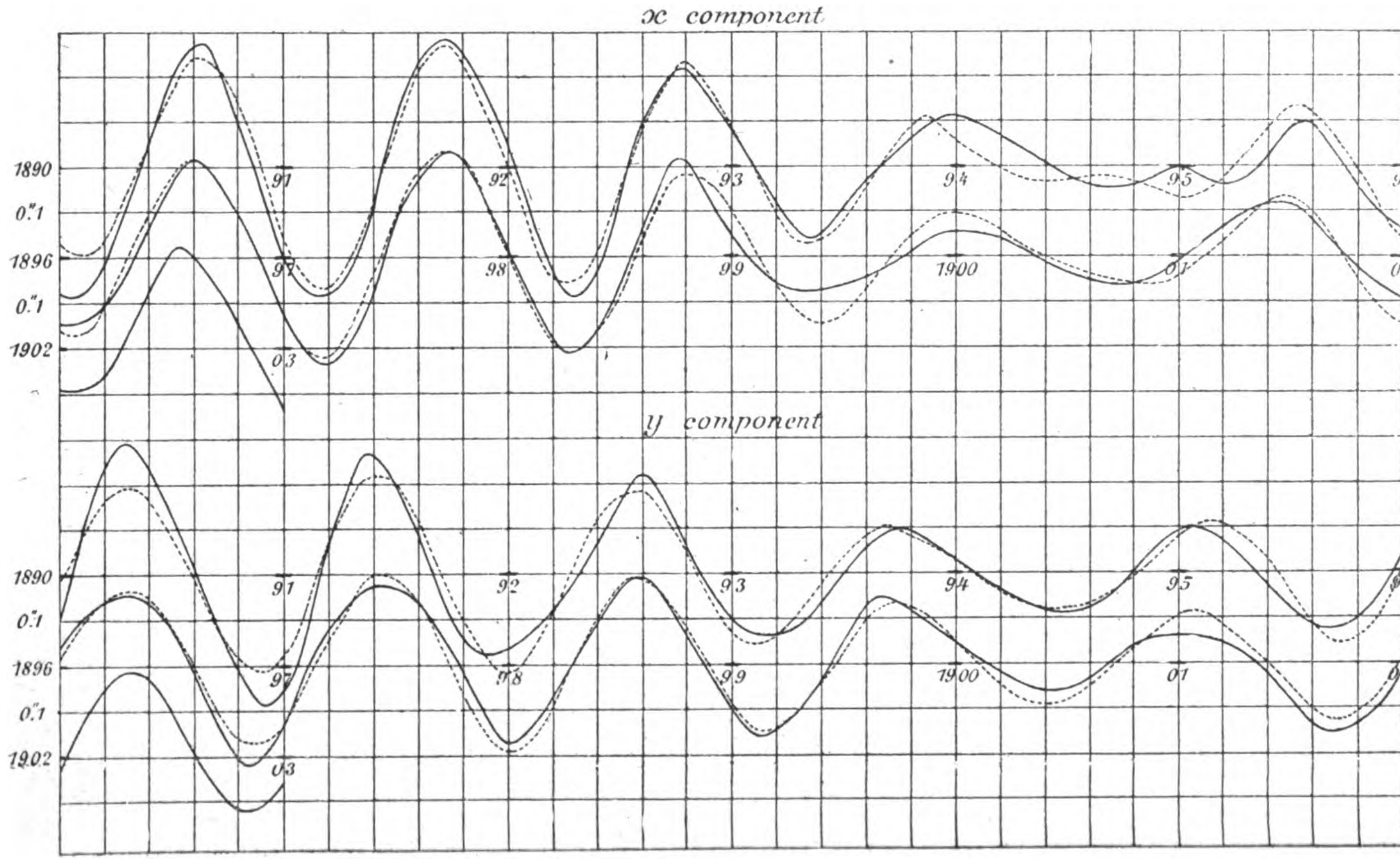
* From *Astronomische Nachrichten*, No. 3932.

Curves of the Components of the Polar Motion.

———Observed...........Computed.



For the sake of easy comparison, the calculated values are also given in the diagram by the dotted curves, which lie closely to those plotted from the observation. The approximate coincidence of these two series of curves for x and y, shows that the polar motion may be pretty well represented by the combinations of two terms of the periods 438^d and 365^d.

On close examination, we find, however, that the sizes of the axes of the annual ellipse vary from year to year, the law of variation being not of a simple character; while the phases remain sensibly the same. Such irregular variations of annual ellipse might generally be attributed to some causes, whose phases are always nearly the same, but whose amplitudes differ for different years, as for instance the meteorological conditions at every place on the Earth. It is, further, to be remarked that the inaccuracies in the value of ξ and the aberration constant affect the annual terms slightly.

While I was occupied with the preceding investigation, I have noticed from the series of observations at each station, that there exists some systematic variation of considerable amount, which can by no means be regarded as of a general character but only of a local. The components x and y, determined from the observations at only a few stations, might have the share of systematic errors peculiar to the localities as well as the observers, the instruments, and the stars observed.

MIZUSAWA, International Latitude Station,
1903 November 6.

PLANET NOTES FOR MAY.

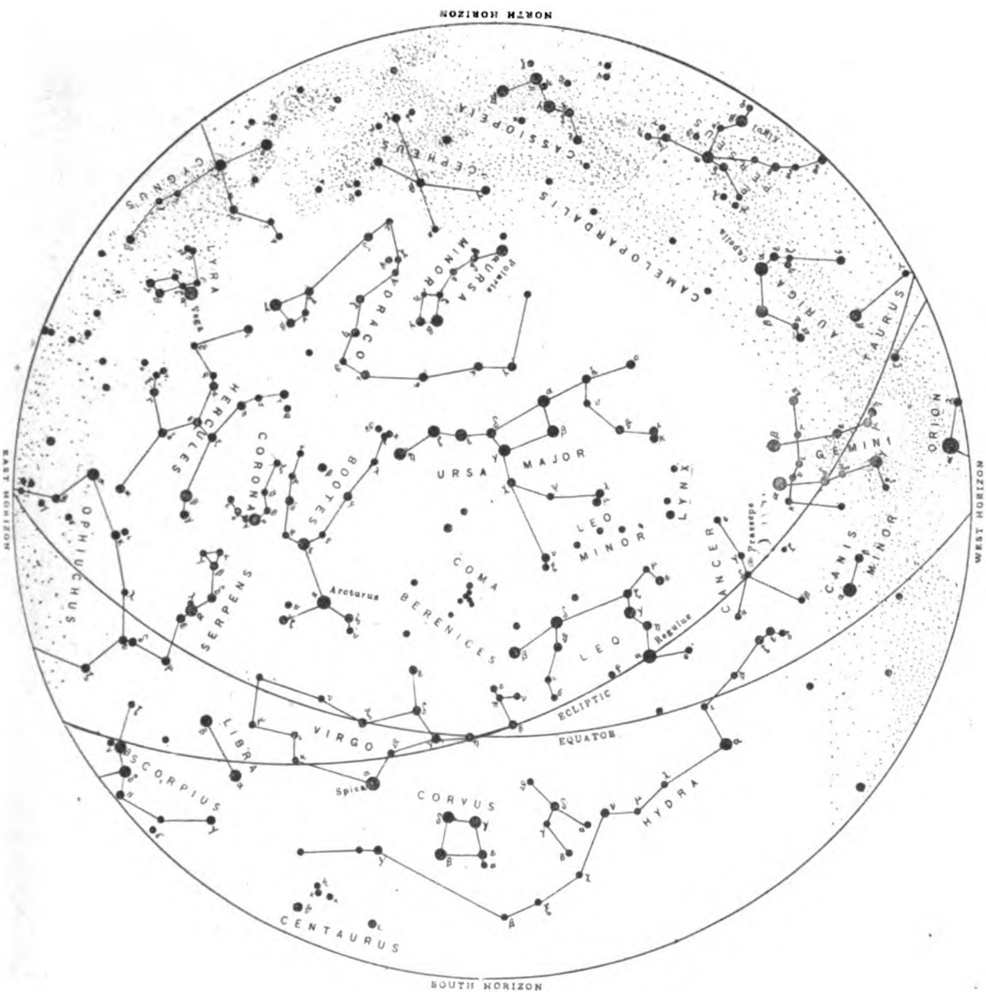
H. C, WILSON.

Mercury will be at inferior conjunction on the morning of May 13, and so will be invisible to the eye during this month.

Venus may be seen in the east an hour before sunrise, and is slowly drawing nearer to the Sun. The disk of the planet is nearly full, but the brightness is near the minimum, because of the great distance at which the planet is seen as well as the glare of the solar rays. On May 22 at 9 A. M., C. S. T., Mercury and Venus will be in conjunction, Mercury being on the nearer side of his orbit while Venus is on the farther side from the Earth. The two are not then in favorable position for observation but it may be possible to see them with the aid of a telescope. At the time of conjunction Mercury will be nearly two degrees south of Venus.

Mars is too close to the Sun for observation, and is on the farther side of his orbit. On May 9 at 4 P. M., C. S. T., Mars and Mercury will be in conjunction

and only 21′ apart in declination, but they cannot be seen even with a telescope at this time. Mars will be at conjunction with the Sun May 30.



THE CONSTELLATIONS AT 9 P. M. MAY 1, 1904.

Jupiter is morning star, and, during the latter days of the month, will be far enough out from the Sun, for those who wish to study its surface markings as continuously as possible to begin their observations.

Saturn will be at quadrature, 90° west from the Sun, May 11 and so may be observed in the morning hours. Look toward the southeast in the constellation Capricorn. There are no stars as bright as Saturn in that vicinity.

Uranus may also be observed in the morning, with the aid of a telescope, in the Milky Way north of γ and west of λ Sagittarii.

Neptune is the only planet observable in the evening, and it will soon be too

low in the west for satisfactory study. For its position see the chart in the March number of POPULAR ASTRONOMY, page 202.

The Moon.

Phases.		Rises. (Central Standard Time at Northfield.	Sets. Local Time 13m less.)
1904		h m	h m
May 7	Last Quarter	1 11 A. M.	11 45 A. M.
15	New Moon	5 14 "	7 51 P. M.
21-22	First Quarter	10 58 "	12 54 A. M.
28-29	Full Moon	7 05 P. M.	5 06 "

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T.			EMERSION. Washington M. T.			Duration.	
			h	m	Angle f'm N pt. °	h	m	Angle f'm N pt. °	h	m
May 1	24 Scorpii	5.2	9	17	81	10	17	308	1	00
8	67 Aquarii	6.2	13	56	3	14	16	327	0	20
19	1 Cancri	5.9	7	45	90	8	46	301	1	01
21	B.A.C. 3398	6.0	10	50	164	11	24	236	0	34
26	B.A.C. 4772	6.6	7	31	161	8	21	246	0	50
26	B.A.C. 4828	6.0	14	48	65	15	37	318	0	49
27	o^2 Libræ	6.3	9	8	149	10	10	252	1	2
30	Y Sagittarii	Var.	16	38	8	16	58	238	0	20

ASTEROID NOTES.

Naming of Asteroids.—The following small planets have recently been named:

No.	Provisional Designation.	Name.	No.	Provisional Designation.	Name.
(360)	1893 N	Carlova	(484)	1902 HX	Pittsburghia
(456)	1900 FH	Abnoba	(488)	1902 JG	Kreusa
(462)	1900 FQ	Eriphyla	(493)	1902 JS	Griseldis
(482)	1902 HT	Petrina	(503)	1903 LF	Evelyn
(483)	1902 HU	Seppina	(507)	1903 LO	Laodica

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	at	Local M. T.		R. A.	Decl.	Mag.
				h m	h m	° ′	
1904 ND	Dugan	Heidelberg	Jan. 27	15 30.2	8 32.1	+ 13 47	11.8
1903 NE	Hirayama	Tokyo	Nov. 26	12 55	4 11.9	44 17	12
1903 NF	Peters	Washington	Dec. 15	11 27.7	5 42.0	9 20	...
1903 NG	Götz	Heidelberg	Oct. 27	14 21.9	3 14.9	19 13	13.0
1904 NH	Charlois	Nice	Feb. 15	9 52.0	9 3.7	+ 18 18	10.5

1904 NA has been found to be identical with (505) [1902 LL] and NH is also identical with (200) Dynamene.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with noon.]

U Cephei.

	d	h
May	•1	22
	4	10
	6	22
	9	10
	11	21
	14	9
	16	21
	19	9
	21	21
	24	9
	26	21
	29	8
	31	20

R Canis Maj.

	d	h
May	2	2
	3	5
	4	8
	5	12
	6	15
	7	18
	8	21
	10	1
	11	4
	12	7
	13	10
	14	14
	15	17
	16	20
	18	0
	19	3
	20	6
	21	9
	22	13
	23	16
	24	19
	25	22
	27	2
	28	5
	29	8
	30	11
	31	15

RR Puppis.

	d	h
May	2	16
	9	2
	15	13
	21	23
	28	9

V Puppis.

	d	h
May	1	5
	2	16
	4	3
	5	14
	7	1
	8	12
	9	23

V Puppis.

	d	h
May	11	10
	12	21
	14	8
	15	19
	17	5
	18	16
	20	3
	21	14
	23	1
	24	12
	25	23
	27	10
	28	21
	30	8
	31	18

S Cancri

	d	h
May	1	18
	11	6
	20	18
	30	5

S Antliæ.

Period $7^h\ 46^m.8$.

	d	h
May	1	4
	2	3
	3	3
	4	2
	5	1
	6	1
	7	0
	7	23
	8	23
	9	22
	10	21
	11	21
	12	20
	13	19
	14	19
	15	18
	16	17
	17	17
	18	16
	19	16
	20	15
	21	14
	22	14
	23	13
	24	12
	25	12
	26	11
	27	10
	28	10
	29	9
	30	8
	31	8

S Velorum.

	d	h
May	4	10
	10	8
	16	7
	22	5
	28	4

W. Urs. Maj.

Period $4^h\ 0^m.2$

May 1-31 7^h

RR Velorum.

	d	h
May	2	9
	4	5
	6	2
	7	22
	9	19
	11	15
	13	12
	15	8
	17	5
	19	1
	20	22
	22	18
	24	15
	26	11
	28	8
	30	4

Z Draconis.

	d	h
May	1	7
	2	15
	4	0
	5	8
	6	17
	8	2
	9	10
	10	19
	12	3
	13	12
	14	20
	16	5
	•17	14
	18	22
	20	7
	21	15
	23	0
	24	8
	25	17
	27	2
	28	10
	29	19
	31	3

δ Librae.

	d	h
May	2	10
	4	18
	7	2
	9	10

δ Libræ.

	d	h
May	11	17
	14	1
	16	9
	18	17
	21	1
	23	9
	25	17
	28	0
	30	8

U Coronae.

	d	h
May	1	23
	5	10
	8	21
	12	8
	15	18
	19	5
	22	16
	26	3
	29	14

R Aræ.

	d	h
May	4	2
	8	12
	12	22
	17	8
	21	19
	26	5
	30	15

U Ophiuchi.

	d	h
May	1	15
	2	12
	3	8
	4	4
	5	0
	5	20
	6	16
	7	12
	8	8
	9	5
	10	1
	10	21
	11	17
	12	13
	13	9
	14	5
	15	2
	15	22
	16	18
	17	14
	18	10
	19	6
	20	2
	20	22
	21	19
	22	15
	23	11

U Ophiuchi.

	d	h
May	24	7
	25	3
	25	23
	26	19
	27	15
	28	12
	29	8
	30	4
	31	0
	31	20

Z Herculis.

	d	h
May	3	0
	4	21
	6	23
	8	20
	10	23
	12	20
	14	23
	16	20
	18	23
	20	20
	22	23
	24	20
	26	22
	28	20
	30	22

RS Sagittarii.

	d	h
May	1	23
	4	9
	6	19
	9	5
	11	15
	14	1
	16	11
	18	21
	21	7
	23	17
	26	3
	28	13
	30	23

RX Herculis.

	d	h
May	1	2
	1	23
	2	21
	3	18
	4	15
	5	13
	6	10
	7	7
	8	5
	9	2
	9	23
	10	21
	11	18
	12	15

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis.

	d	h
May	13	13
	14	10
	15	7
	16	5
	17	2
	17	23
	18	21
	19	18
	20	15
	21	13
	22	10
	23	7
	24	5
	25	2
	25	23
	26	21
	27	18
	28	16
	29	13
	30	10
	31	8

RV Lyræ.

	d	h
May	3	17
	7	7
	10	21
	14	11
May	18	2
	21	17
	25	7
	28	21

U Sagittæ.

	d	h
May	2	1
	5	10
	8	20
	12	5
	15	14
	18	23
	22	8
	25	17
	29	2

SY Cygni.

	d	h
May	1	17
	7	17
	13	17
	19	17
	25	18
	31	18

SW Cygni.

	d	h
May	1	12
	6	1
	10	15
May	15	5
	19	20
	24	9
	28	23

UW Cygni.

	d	h
May	4	2
	7	13
	11	0
	14	11
	17	21
	21	8
	24	19
	28	6
	31	17

W Delphini.

	d	h
May	1	5
	6	0
	10	20
	15	15
	20	10
	25	6
	30	1

VV Cygni.

	d	h
May	1	23
	3	10

V VCygni.

	d	h
May	4	22
	6	9
	7	21
	9	8
	10	19
	12	7
	13	18
	15	6
	16	17
	18	5
	19	16
	21	4
	22	15
	24	3
	25	14
	27	1
	28	13
	30	0
	31	12

VW Cygni.

	d	h
May	9	0
	17	11
	25	21

Y Cygni.

	d	h
May	1	18
	3	3
	4	18
	6	3
	7	17
	9	2
	10	17
	12	2
	13	17
	15	2
	16	18
	18	2
	19	17
	21	2
	22	17
	24	2
	25	17
	27	2
	28	17
	30	2
	31	17

UZ Cygni.

	d	h
May	19	5

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.6$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
May	1	10	May	9	6	May	17	3	May	24	23
	2	13		10	9		18	6		26	2
	3	16		11	12		19	9		27	5
	4	19		12	15		20	12		28	8
	5	22		13	18		21	14		29	11
	7	1		14	21		22	17		30	14
	8	3		16	0		23	20		31	17

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
May	1	18	May	9	19	May	17	20	Apr.	25	21
	2	18		10	19		18	20		26	21
	3	18		11	19		19	20		27	21
	4	18		12	19		20	21		28	22
	5	19		13	20		21	21		29	22
	6	19		14	20		22	21		30	22
	7	19		15	20		23	21		31	22
	8	19		16	20		24	21			

Variable Stars of Short Period not of the Algol Type.

	Minimum. d	h	Maximum. d	h
S. Triang. Austr.	May 1	2	May 3	4
V Velorum	1	23	2	22
W Virginis	2	7	10	12
T Velorum	2	8	3	17
T Vulpeculae	2	8	3	27
β Lyrae	2	22	6	0
R Crucis	3	13	4	22
Y Sagittarii	3	14	5	9
V Carinae	3	16	5	20
δ Cephei	3	19	5	4
η Aquilae	3	20	6	5
U Sagittarii	3	22	6	21
S Normae	3	23	8	9
SU Cygni	4	2	5	10
S Crucis	4	22	6	10
ζ Geminorum	5	1	10	1
V Centauri	5	7	6	18
RV Scorpii	5	21	7	7
κ Pavonis	6	3	9	22
V Velorum	6	8	7	7
X Cygni	6	11	12	16
T Vulpeculae	6	18	8	3
W Sagittarii	6	21	9	21
T Velorum	6	23	8	7
U Vulpeculae	7	3	9	6
T Crucis	7	8	9	9
S Trianguli Austr.	7	10	9	12
W Geminorum	7	11	10	2
X Sagittarii	7	17	10	14
S Sagittæ	7	18	11	4
SU Cygni	7	22	9	6
U Aquilae	7	23	10	3
S Muscae	8	12	11	23
δ Cephei	9	4	10	13
Y Sagittarii	9	8	11	3
R Crucis	9	9	10	18
β Lyræ	9	9	12	16
S Crucis	9	15	11	3
TX Cygni	10	5	15	8
V Carinae	10	8	12	12
U Sagittarii	10	16	13	15
V Velorum	10	16	11	15
V Centauri	10	19	12	6
η Aquilae	11	0	13	9
T Vulpeculae	11	4	12	13
T Velorum	11	15	13	0
SU Cygni	11	19	13	3
RV Scorpii	11	22	13	8
S Normae	13	17	18	3
S Triang. Austr.	13	18	15	20
Y Ophiuchi	13	22	20	3
T Crucis	14	1	16	2
S Crucis	14	7	15	19
W Sagittarii	14	11	17	11
δ Cephei	14	13	15	22
X Sagittarii	14	18	17	15
U Aquilae	15	0	17	4
V Velorum	15	1	16	0
Y Sagittarii	15	2	16	21
U Vulpeculae	15	2	17	5
R Crucis	15	5	16	14
κ Pavonis	May 15	5	May 19	0
W Geminorum	15	5	17	20
ζ Geminorum	15	5	20	5
T Vulpeculae	15	15	17	0
SU Cygni	15	15	16	23
β Lyrae	15	20	18	22
S Sagittae	16	3	19	13
T Velorum	16	6	17	15
V Centauri	16	7	17	18
V Carinae	17	1	19	5
U Sagittarii	17	10	20	9
RV Scorpii	18	0	19	10
S Muscae	18	3	21	14
η Aquilae	18	4	20	13
S Crucis	19	0	21	12
V Velorum	19	10	20	9
SU Cygni	19	11	20	19
W Virginis	19	14	27	19
δ Cephei	19	22	21	7
T Vulpeculae	20	1	21	10
S Triang. Austr.	20	1	22	3
T Crucis	20	19	22	20
Y Sagittarii	20	21	22	16
T Monocerotis	20	21	28	19
T Velorum	20	22	22	7
R Crucis	21	0	22	9
X Sagittarii	21	18	24	15
V Centauri	21	19	23	6
U Aquilae	22	0	24	4
W Sagittarii	22	1	25	1
β Lyrae	22	7	25	14
X Cygni	22	20	29	1
U Vulpeculae	23	2	25	5
SU Cygni	23	7	24	15
S Normae	23	11	27	21
S Crucis	23	17	25	5
V Carinae	23	17	25	21
V Velorum	23	19	24	18
RV Scorpii	24	1	25	11
U Sagittarii	24	4	27	3
κ Pavonis	24	7	28	2
S Sagittae	24	12	27	22
T Vulpeculae	24	12	25	21
TX Cygni	24	23	30	2
δ Cephei	25	7	26	16
η Aquilae	25	8	27	17
ζ Geminorum	25	8	30	8
T Velorum	25	22	27	7
S. Triang. Austr.	26	9	28	11
Y Sagittarii	26	15	28	10
R Crucis	26	20	28	5
SU Cygni	27	4	28	12
V Centauri	27	7	28	18
T Crucis	27	12	29	13
S Muscae	27	19	31	6
V Velorum	28	4	29	3
S Crucis	28	10	29	22
β Lyræ	28	18	31	20
X Sagittarii	28	18	31	15
U Aquilae	29	1	31	5
W Sagittarii	29	16	32	16

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
RV Scorpii	May 30	3	May 31	13	U Sagittarii	May 30	22	May 33	21
T Velorum	30	5	31	14	SU Cygni	31	0	32	8
V Carinæ	30	11	32	15	U Vulpeculae	31	1	33	4
δ Cephei	30	16	32	1	Y Ophiuchi	31	1	37	6

Approximate Magnitudes of Variable Stars Feb. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	9*i*	R Camel.	14	25.1	+84	17	12*d*
T Cassiop.	0	17.8	+55	14	8*d*	R Bootis	14	32.8	+27	10	9*i*
R Androm.	0	18.8	+38	1	7*d*	S Librae	15	15.6	—20	2	*f*
S Ceti	0	19.0	— 9	53	*s*	S Serpentis	15	17.0	+14	40	15*f*
W Cassiop.	0	49.0	+58	1	*u*	S Coronae	15	17.3	+31	44	7*i*
S "	1	12.3	+72	5	13*d*	S Urs. Min.	15	33.4	+78	58	8*d*
R Piscium	1	25.5	+ 2	22	13*f*	R Coronae	15	44.4	+28	28	6
R Trianguli	1	31.0	+33	50	10*d*	V "	15	45.9	+39	52	8
U Persei	1	52.9	+54	20	11*d*	R Serpentis	15	46.1	+15	26	13*f*
R Arietis	2	10.4	+24	36	13*d*	R Herculis	16	1.7	+18	38	12*d*
o Ceti	2	14.3	— 3	26	3	R Scorpii	16	11.7	—22	42	*u*
S Persei	2	15.7	+58	8	11*d*	S "	16	11.7	—22	39	*u*
R Ceti	2	20.9	— 0	38	7*i*	U Herculis	16	21.4	+19	7	7*i*
U "	2	28.9	—13	35	*s*	R Ursae Min.	16	31.3	+72	28	*u*
R Persei	3	23.7	+35	20	13	W Herculis	16	31.7	+37	32	10*d*
R Tauri	4	22.8	+ 9	56	11*d*	R Draconis	16	32.4	+66	58	8*i*
S "	4	23.7	+ 9	44	11*d*	S Herculis	16	47.4	+15	7	12*d*
R Aurigæ	5	9.2	+53	28	8*i*	R Ophiuchi	17	2.0	—15	58	11*d*
U Orionis	5	49.9	+20	10	10*i*	T Herculis	18	5.3	+31	0	11*i*
R Lyncis	6	53.0	+55	28	12*d*	R Scuti	18	42.2	— 5	49	*s*
R Gemin.	7	1.3	+22	52	12*d*	R Aquilae	19	1.6	+ 8	5	*u*
S Canis Min.	7	27.3	+ 8	32	8	R Sagittarii	19	10.8	—19	29	*s*
R Cancri	8	11.0	+12	2	10*d*	S "	19	13.6	—19	12	*s*
V "	8	16.0	+17	36	8*i*	R Cygni	19	34.1	+49	58	11*d*
S Hydrae	8	48.4	+ 3	27	9*d*	RT "	19	40.8	+48	32	*s*
T "	8	50.8	— 8	46	8*d*	X "	19	46.7	+32	40	9*d*
R Leo. Min.	9	39.6	+34	58	11*d*	S Cygni	20	3.4	+57	42	*f*
R Leonis	9	42.2	+11	54	10*d*	RS "	20	9.8	+38	28	8
R Urs. Maj.	10	37.6	+69	18	13*f*	R Delphini	20	10.1	+ 8	47	*s*
R Comae	11	59.1	+19	20	*f*	U Cygni	20	16.5	+47	35	8*i*
T Virginis	12	9.5	— 5	29	9*i*	V "	20	38.1	+47	47	*f*
R Corvi	12	14.4	—18	42	9*d*	T Aquarii	20	44.7	— 5	31	*s*
Y Virginis	12	28.7	— 3	52	9*i*	R Vulpec.	20	59.9	+23	26	*s*
T Urs. Maj.	12	31.8	+60	2	12	T Cephei	21	8.2	+68	5	6*i*
R Virginis	12	33.4	+ 7	32	7*d*	S "	21	36.5	+78	10	8*d*
S Urs. Maj.	12	39.6	+61	38	12	S Lacertae	22	24.6	+39	48	12
U Virginis	12	46.0	+ 6	6	*f*	R "	22	38.8	+41	51	14*f*
V "	13	22.6	— 2	39	12*d*	S Aquarii	22	51.8	—20	53	*s*
R Hydrae	13	24.2	—22	46	5*i*	R Pegasi	23	1.6	+10	0	*s*
S Virginis	13	27.8	— 6	41	12*d*	S "	23	15.5	+ 8	22	*s*
R Can. Ven.	13	44.6	+40	2	10*i*	R Aquarii	23	38.6	—15	50	*s*
S Bootis	14	19.5	+54	16	13*d*	R Cassiop.	23	53.3	+50	50	7*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, McCormick, and Harvard Observatories.

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

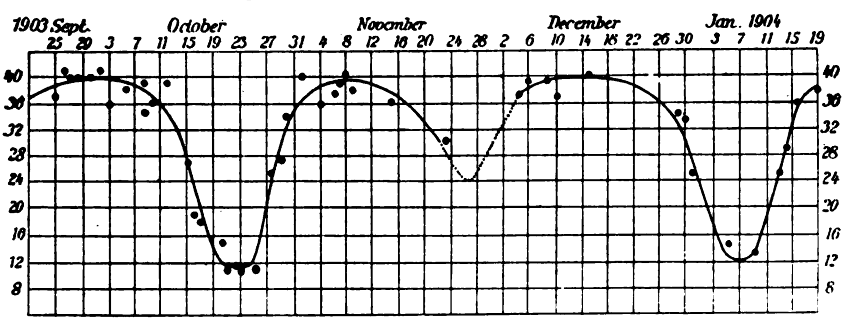
	d	h		d	h		d	h		d	h
May	2	0	May	10	4	May	18	8	May	26	13
	3	0		11	5		19	9		27	13
	4	1		12	5		20	9		28	14
	5	1		13	6		21	10		29	14
	6	2		14	6		22	11		30	15
	7	3		15	7		23	11		31	15
	8	3		16	7		24	12			
	9	4		17	8		25	12			

New Variable Star 4.1904 Vulpeculæ.—This star appears to be of the type of β Lyræ and is announced in *A. N.* 3929 by Mr. A. Stanley Williams. It is BD. + 26°3937, 8.1^m, and its position for 1855 is

R. A. $20^h\ 30^m\ 21^s.86$ Decl. + 26° 06′ 11″.8.

The range of variation appears to be from about 8.0 to 9.7 magnitude in a period of 75 days. A secondary minimum occurs somewhere near 33 days after the principal minimum. Mr. Williams gives the following approximate elements for the principal minimum:

Principal minimum = J. D. 2416486 + $75^d.3$ E.



Light Curve of 4.1904 Vulpeculæ.

The accompanying cut shows the light curve as determined by Mr. Williams from 45 visual observations between Sept. 25, 1903 and Jan. 19, 1904.

New Variable 5.1904 Vulpeculæ and 6.1904 Cassiopeiæ.—These are both announced in *A. N.* 3926 by Professor Ceraski of Moscow. Their positions are

	°	α 1855 h m s	δ 1855 ° ′	α 1900 h m s	δ 1900 ° ′
5.1904 =	BD + 25 4126	20 23 59.3	+ 25 51.8	20 05 52.3	+ 25 59.4
6.1904 =	BD + 67 244	2 54 51	+ 67 00.6	2 58 49	+ 67 11.6

5.1904 was suspected of variability by Yendell (A. J. 346) and Espen (A. N. 3232). Its magnitude is given in the BD. as 9.3. According to the photographs at Moscow the variation is about one magnitude (between 9.0 and 10.0). The period is not yet determined and is perhaps irregular.

6.1904 is generally constant, but is occasionally found to be about 0.6^m fainter than ordinarily. The observations are insufficient to determine whether it is an Algol type variable or not.

New Variable Star 7.1904 Cygni.—This is announced in *A. N.* 3932 by Professor Ceraski. It is BD. + 42°.4233, 8.3^m and its position is

For 1855	R. A. 21^h 45^m $53^s.9$	Decl. + 42° 27′.5
For 1900	21 47 41 .8	+ 42 40 .1

From 20 photographs, during the years 1898-1903, M. Blajko has concluded that the star varies between 8.2 and 9.2 magnitude and that the period is short, not more than five days and perhaps only some hours.

New Variable Star 8.1904 Orionis.—Professor Max Wolf finds on two plates, taken Jan. 10, 1904 with 3¾ hours exposure, a star a little below the 11th magnitude, of which no trace is found upon several plates in the preceding years on which stars of the 15th magnitude were shown. The star is not far from the variable 85.1901 Orionis in the waves of the nebula. Its position for 1900 is

R. A. 0^h 30^m $55^s.8$ Decl. — 5° 20′ 25″

U Geminorum.—This star has just passed a short maximum. On March 4 it was at 13.3 magnitude, but on March 8 it was found at 9.9 magnitude. The next night it appeared somewhat brighter. A rapid decrease then set in, and on March 15 the star had sunk to 12.6 magnitude.

Two other maxima have been observed here during the past year. The first was a short one at the end of September; the second was a long one in the middle of December. ZACCHEUS DANIEL.

PRINCETON, N. J., 1904 March 16.

GENERAL NOTES.

During the last three issues of this publication, our mechanical work has been much hindered, and we have come late each month, especially to reach foreign subscribers. The chief cause of this delay has been due to the fact that the new type-setting machine, promised some time ago, has not yet arrived. We have assurances now that the new machine will be ready for business in a very few days.

In view of the large use of a machine for setting our type in the future, correspondents furnishing matter for publication, will please take great care in preparing copy, so that it may be as nearly accurate as possible to save time and expense in correcting proofs.

Personal Notice.—Harold Jacoby, Ph. D., Adjunct Professor of Astronomy at Columbia University, New York, has been promoted to a professorship. Professor Rees, who has been away since December, 1902, on account of illness, has had his leave extended until July, 1905. Professor Jacoby will continue as Acting Director of the Columbia University Observatory during the interval.

Charles L. Poor, Ph. D., formerly at the Johns Hopkins University, has also been appointed a Professor of Astronomy, and will be associated with Professor Jacoby at Columbia.

Photographic Observations of Comet 1903 *c* (Borrelly.)—Lick Observatory Bulletin No. 52 is wholly given to an account of the photographic observations of comet 1903 *c* (Borrelly), made by Sebastian Albrecht. The Bulletin bears date Jan. 12, 1904. The paper is accompanied by two full page plates containing twelve reproductions of the photographs of the comet between July 15, 1903, and Aug. 15, 1903. The exposures range in time from one hour to six hours. In the latter part of July occur the long exposures when the remarkable changes were going on in the tail of the comet. The photograph taken July 24 between 9^h and $14^h\ 30^m$ is a good one at a critical time. It is to be regretted that the plate for July 26 does not show well the break in the tail at that date.

Apparent Changes in Some of the Canals of Mars.—In Bulletin No. 8 from his observatory, Mr. Lowell gives evidence of apparent changes in a few of the canals he has had under observational study for some time past. He calls particular attention to those canals named Thoth and Amenthes at the opposition of Mars in 1903.

In 1877 Schiaparelli observed and mapped a set of three canals which lay east of Syrtis Major which he named the Thoth, the Triton and the Nepenthes. These markings Schiaparelli must have seen well for he describes them and other markings near by so clearly that they have been identified certainly years later by other observers, although it is noteworthy that he did not discover each and all of them at the same time.

Mr. Lowell in the paper referred to gives a full and detailed account, of the apparent changes, disappearance and reappearance of these markings as reported by Schiaparelli in his memoirs which appeared between 1877 and 1888; he also gives a detailed account of his own study of the same region and makes some suggestions about it worthy of general attention. A part of the concluding paragraph of his paper is as follows:

"Knowing as we now do that that mutable form of matter, the liquid, is largely absent from Mars, that there are no large bodies of water on the surface of the planet and very little of it in any form, we perceive no material means by which such local change in appearance from year to year could be effected. Indeed, even the presence of water would not render the explanation more feasible by the supposition of freshet or other inundation, since if such were able to cause a new marking it could not on that account obliterate the old. There could be no selective action by which the one should be taken and the other left. Nor could meteorological causes very well produce what we see since they would be too impotent, it would seem, to decide that of two possible effects, alike except for a slight shift of locality, and only two, the one should always occur to the exclusion of the other. A year might be wet or dry but it could not well be wet in one place invariably when it was dry in another substantially the same and, what is the crux in the matter, never productive of any mean between the two except as the one gave of its humidity to the other. We are, therefore, led to the conclusion that the two canals do not wax and wane separately from natural causes but are in truth alternatives so connected that the one should increase as the other decreases and vice versa. To explain this state of things, the most probable supposition we can make is that they are so constructed, and that the one lies fallow while the other is at work. It is easily conceivable that a limited water supply should involve a necessity of the sort. It may well be that after one district has enjoyed the water and its results for a certain period,

the supply should then be turned for a time into a neighboring one to be turned back again after a while. The idea follows as a corollary from the theory that the canals perform the office of water supply, and in so far strengthens that theory itself."

The Revised Harvard Photometry.—A catalogue giving the photometric magnitudes of about nine thousand stars, is now approaching completion. All stars in any part of the sky and of the magnitude 6.5 and brighter in any of our photometric catalogues are included. The magnitude of each star will be shown according to each photometric catalogue, whether published here or elsewhere, also its various designations and its class of spectrum. These magnitudes can now be furnished to any astronomer who needs them, and it is expected that in a few months the catalogue will be in the hands of the printer.

The best method of placing the results represented by our photographs in the hands of astronomers is a serious question. Photo-engravings of enlargements of the original negatives are very expensive, and besides reproducing the defects in the original photographs add others of their own. Far more can be shown per square inch on a glass negative than on a paper print. The photographs taken with the Arequipa and Cambridge Anastigmatic lenses cover regions rather more than 30° square on an 8 x 10 plate. Although the aperture but little exceeds one inch, stars as faint as the twelfth magnitude are obtained with exposures of about sixty minutes. Fifty-five of these negatives were selected, covering the entire sky. Contact prints were made from these, and printing from them gave sets of negatives closely resembling the originals, except that the stars were larger and more easily seen. These sets, covering the entire sky, and showing stars down to about the twelfth magnitude, were then offered to astronomers for $15.00, or less than the original cost. The deficit has been charged to the Advancement of Astronomical Science Fund of 1902.

Burnham's Double Star Measures at Yerkes Observatory in 1900 and 1901.—This quarto volume of 75 pages is the work of S. W. Burnham with the 40-inch refractor of Yerkes Observatory during the years 1900 and 1901, and forms part of volume VIII, titled Astronomy and Astrophysics, in the first series of the decennial publications of the University of Chicago.

This paper is concerned with the double star measures that have been made since the completion of Burnham's General Catalogue of 1290 double stars, discovered almost entirely by himself between the years 1871 and 1899, and published in 1900 as Vol. 1 of the Publications of the Yerkes Observatory.

After the publication of the General Catalogue, Mr. Burnham gave his attention to some needed double star work which appears in this paper now before us. All double star observers will be interested in the make-up of his working lists. Mr. Burnham included in those lists stars not likely to be observed elsewhere, long neglected and little known pairs and those which for lack of sufficient measures, or, because of uncertainty of the early results could not be classified in regard to motion or otherwise. For two reasons Mr. Burnham could undertake such pieces of work as these as almost no other astronomer could hope to do as fully and as well as could be expected of him. In the first place he knows the literature of double star astronomy exceptionally well; and in the second place, he has, in the regular use of the great 40-inch refractor of Yerkes Ob-

servatory instrumental power sufficient to test the most delicate and the most difficult cases of visual separation of the components of binaries that are likely to be undertaken anywhere. If his regular share of time at the Yerkes telescope is not sufficient, he has ready access, as in the past, to the 18½-inch Clarke refractor of Dearborn Observatory at Evanston, which instrument Mr. Burnham is proud of, because of its excellent defining power.

On the other hand when we consider the work of the Herschels and South in their several catalogues, the wider doubles which have been long neglected since the time of those early observers presented a needy field of work, because if these wider doubles are true binaries, their circular motion must be extremely slow, and it requires the skill of a first rate astronomer in this science to distinguish between the proper motion of the two and the circular motion of a very slow binary system. Only the very best measurements in such cases are worth very much for records that will be useful at present or in years to come. It must be apparent to Mr. Burnham from this late work in the older fields of double-star observing if he has not known it years ago, that the best work on record from 80 to 100 years ago, including that of the Herschels, now so well thought of, was somewhat deficient in method and care. If one looks over the work of this volume, he will see that Mr. Burnham does not allow his work to go on record with single measures of position-angle, or with estimates of distances of components, as these early observers sometimes did who worked 80 or 100 years ago, and with whose results he now seeks to compare his own. It is quite evident that the comparisons now made, in some cases at least, would be more favorable and more certain than any one can now be sure of. When we see that Mr. Burnham's measures taken two or three times over, on every double star, show variation in hundredths places in micrometer revolution for distances of components, and in tenths of degrees for position angles. The results are in compact form, each set being accompanied by brief notes of interest pertaining to the particular star or stars under measurement.

We notice in the last part of the volume that Mr. Burnham has discovered in the process of this work nearly twenty new double stars, some of them being exceedingly close pairs. One in particular is recorded as having a distance between components of only $0''.21$. Observers of double stars will want this publication for study and for reference.

The Mechanics of the Universe is the title of a paper recently prepared by Herman T. C. Kraus, C. E., of Brooklyn, N. Y. It consists of 32 pages, with a brief preface, and gives as its full title: Motion; The fundamental principles of mechanics; or, The mechanics of the universe.

We are sorry to know that any modern civil engineer would commit to the printed page what is apparently hurried, off-hand thinking on such a difficult theme as that which the author of this paper has chosen. He says: "Mathematics have purposely been omitted; for by figures nothing can be ascertained unless they run in a true channel of correct theory."

"The author could not work out details, for this would have required several stout volumes, for the production of which he has neither the time nor the means. The suggestions are made without the consultation of books, nor with the assistance of anybody, so as not to be influenced in the right course."

My stars what a confession! Is this the science of the twentieth century? If Newton, La Place and La Grange had only lived until this time we wonder if they would have said that possibly their mathematics do not "run in a true channel of correct theory!"

A New Incandescent Lamp.—Photographers who can refer to the "Photographisches Wochenblatt" for the 1st of this month may see the illustration of a new incandescent lamp, the invention of Professor Drehschmidt. It burns petroleum, and gives a light equal to 2,200 standard candles. It has no wick, and may, therefore, be classed with the Kitson light. It differs from the latter in the construction of the generator, which is claimed to be more simple in the Drehschmidt lamp. The light is started by ignition of a small quantity of methylated spirit, aud actuating a small air pump, worked by hand. When the lamp is warmed up sufficiently, it appears to require no more attention. A pressure-guage indicates any variation, and a falling off in the light may be remedied by means of the air pump. If the lamp is well constructed and does all that is claimed for it, there should be plenty of scope for its use by photographers. Portraits have been taken by its light in from five to seven seconds, and collodio-chloride prints have been made in thirty-five minutes. It is therefore nearly comparable with diffused daylight. For enlarging and the exhibition of lantern slides it should be of great value. The mantles cost eighteen pence, and last for one hundred hours' use. The cost of the petroleum is about one penny per hour.—The British Journal of Photography.

International Exchange Service of the Smithsonian Institution.—We have received a copy of the International Exchange List of the Smithsonian Institution, Washington, D. C., corrected to September, 1903. This branch of the Government service works through the channel, "For the increase and diffusion of knowledge," and is certainly one of the most useful of its kind for the advancement of science known to our present international relations. The last issue of this exchange list makes a thick volume of 492 pages and contains 12,720 addresses in all parts of the world that are entitled to its privileges.

The main purpose of this exchange service is to materially assist institutions and individuals in this country in the transmission of their publications abroad, and also, foreign societies and individuals in distributing their publications in the United States. Any one can readily see how such an arrangement for free registered service would materially assist astronomers who are in all parts of the world in work such as theirs that is essentially related and interrelated in all its various branches. This exchange system is so complete and prompt in its service that the fast mails in every land give it their careful attention, and the result is, astronomers read the work that is done anywhere in the world by their associates very soon after it is completed. It is ranked only by the free telegraphic service that is given to the transmission of astronomical discoveries. Scientific institutions are under great obligations to the Government for such material aid in their work.

The Sun in January, 1904.—The month of January, with the exception of a few of the last days was marked by fine activity in the Sun. There appeared new spots on the Sun on the following days: 3rd, 6th, 13th and 15th; but these spots made their appearance in the regular way, that is to say, showed themselves at the eastern limb and traversed the Sun towards the western edge. Besides these spots, there were some others which were the result of sudden explosions. One of them occurred on the 17th of the month, but it was not very remarkable. Another, extremely curious one, was that of the 22nd. Suddenly

appeared near the center of the Sun fifteen spots, without penumbra, which affected the shape of a J.

On the following day the transformation had been complete. One of the spots was very large, had a fine penumbra and three umbras and near this spot there were twenty-five little spots. Were they not fine? On the following day—Sunday, the 24th—many friends of mine, members of the *Sociedad Astronomica de México* came to my Observatory in order to observe this splendid group, whose general shape was that of a pipe. This fine group disappeared on the 27th. Then commenced a period of calm and it was such a complete one that on the 31st of the month not a single spot was visible on the Sun.

How we may best observe. This is very important for the amateur. The easy way to observe sun-spots consists in projecting them on white card-board, but this ought to be done in a dark room in order to get the minute details of the penumbra and the shape of faculæ. But no method gives such good results as to view the Sun directly through the telescope, using, of course a dark glass or *helioscope*.

The expert Father Secchi recommended sketching on black paper with white paint by means of a little brush; but this is not an easy thing. My clever friend l'Abbe Th. Moreux likes better to draw with sepia color on dark paper.

I think that it is a good and easy way to draw with a soft pencil on dark paper, bluish or grayish, marking the faculæ with white pencil. Only when the drawing is going to be reproduced by the photo-engraving process it is better to draw with china ink on white paper.

In any case, we must not forget to keep a complete collection of our drawings in a note-book, for comparison work. LUIS G. LEON.

CITY OF MEXICO, February 1st, 1904.

Meeting of the British Astronomical Association Jan. 27 1904.—At this meeting there were some interesting questions discussed, one of which was: "The Aspects of the Nebular Hypothesis." The paper on this subject, if correctly reported in the March *Observatory* suggested that it would be better to call that celebrated hypothesis "nebulous" instead of "nebular" and then it went on to some length in support of that contention, making out as one of the speakers said, something of a case against the hypothesis as it is now generally accepted. Several prominent English astronomers participated in the discussion, but, from the report, we do not see that any new or advance ground was made on which astronomers may stand for new work or further advancement in knowledge of theory. Is not Newcomb right in saying we must have more data?

The Stars, a Study of the Universe, which is the title of Professor Simon Newcomb's recent book, received favorable notice in the remarks made by Mr. Crommelin at the January meeting of the British Astronomical Association. He said, "*The Stars, a Study of the Universe,* brought out very forcibly the true grandeur of the Milky Way because he there demonstrated, perhaps, for the first time, how enormously distant it was."

For years past the extent of the universe has occupied the attention of Professor Newcomb largely, and his public utterances on the theme have attracted

the notice of astronomers very generally at home and abroad. It may not be saying too much if we should claim that they have stimulated and are directing in some degree, some of the best astronomical work now going on in America.

Barnard's Micrometrical Observations of the Planet Eros.— The paper before us is another one of those strong pieces of astronomical work that forms part of Vol. VIII of the decennial publications of the University of Chicago. These micrometrical observations of the minor planet Eros were made by Professor E. E. Barnard with the great 40-inch refractor of the Yerkes Observatory during the opposition of 1900-1901. It is probably known to most of our readers that this work with the filar micrometer was part of the general scheme for a systematic series of such observations in this country and in Europe, as an aid for the re-determination of the solar parallax.

In the introductory and explanatory part of these observations, some curious features appear which indicate how the different parts of the great telescope work together in making up the results of observation. Mr. Barnard has applied no correction to the micrometer screw for temperature, because both screw and tube of the telescope are of steel, and, of course, of the same coëfficient, and because they act in opposite directions they mutually cancel each other. A change in the length of the screw by heat or cold is compensated by a corresponding change in length of the tube. This is somewhat surprising in view of the great difference in mass of the two parts. Mr. Barnard has doubtless thoroughly proved this point and knows whereof he speaks. We know he is not likely to admit any uncertainties in his results without giving ample notice of such facts. In carrying observations of Atlas and Pleione of the Pleiades for five years, he found that the change in focal length of the great glass alone is to be taken into account, and only a portion of that—the difference the change in the tube and the change in the focus. For example, from summer to winter the focus shortens from the action of cold on the lens. The shortening of the focus is greater than that of the tube, the extreme difference being about 0.3 inches, though the entire shortening of the focus is upwards of three-fourths of an inch.

The behavior of the polar axis of the telescope during the winter of 1901-2, furnishes another point of interest in regard to the stability of large and heavy mountings in such delicate astronomical tests as those which Mr. Barnard applied to this instrument by the observation of a great many stars for this particular purpose. The result was:

North end of polar axis too low	0′ 39″
North end of polar axis too far west	0′ 45″

In the winter of 1897 the position was:

North end of polar axis too low	0′ 10″
North end of polar axis too far west	1′ 00″

apparently a good showing in regard to harmful change of place.

This quarto paper has only 40 pages in it, but it means work, and a large amount of it. The explanatory part is brief and to the point, and then comes solid pages of figures by the score, giving full data of the observations and the results of reduction up to and including the parallax factors in right ascension and declination. Tables follow showing the comparison stars used, barometer and thermometer records, and other information deemed useful in this work.

This paper appears to present a very full and thorough study of the posi-

tions of the planet Eros between October 2, 1900 and February 5, 1901. We notice that there is an error at the top of page 25 and on several others following, in regard to the year. This will not mislead any one probably because, in the body of the table, page 24, the correct year is given. There are also other tables of observations of Eros, for other years, making this line of work quite as complete as could be expected from any single observer.

The one thing that we regret about the micrometrical measures of Eros is what Mr. Barnard has already mentioned to us, in a personal interview a few months ago. That was, that some one person competent to make the micrometrical measures and also to photograph the same regions should carry the two lines of work right along side by side under the same conditions, with the same instruments, at the same time. If this could have been done, it seems strongly probable that much of the error that is now to be feared, for a lack of these circumstances, might possibly have been eliminated from the results that must be combined from sources that must greatly vary in all these particulars.

Two Stars with Variable Radial Velocity.—We have been much interested in reading the accounts given by Frost and Adams in the study of the radial velocities of stars where there seems to be variation. In the course of recent work with the Bruce spectrograph Yerkes Observatory on stars having spectra of the *Orion* type the two stars *u* Herculis and 57 Cygni have been found to show large variation in their radial velocities. Four consecutive results on the first star are — 65, — 44, + 101, + 98 kilometers of velocity. These measures may be in error, as the observers think, by several kilometers, because the lines of its spectrum are broad and diffuse. But the star is one of special interest on account of its being a photometric variable of irregular period.

The other star, 57 Cygni, also shows large variation in radial velocity in the two results given, viz: — 114, — 23. An interesting fact also appears on one of the plates, when the magnesium line at λ 4481.4 appears to have a second component, which is displaced toward the red by an amount corresponding to a velocity of about + 56 km. No second component can be seen on the other of the two plates from which the above results come. These observers say: "In this connection it may be stated that on different plates we often find marked differences in the distinctness of the lines in spectra of stars varying rapidly in veloc. ity, doubtless in part due to the change in velocity during the exposure."

In recent articles these observers have called attention to other stars having large variation of velocity in the line of sight. This must certainly prove to be a new and most fascinating field of research for observers in it who have the instrumental equipment equal to its needs.

Astronomical and Astrophysical Society will hold its next meeting at Philadelphia during Convocation week 1904-05, in affiliation with the Ameri-Association for the Advancement of Science.

H. Struve, Director of the Observatory at Königsburg has been appointed Director of the Observatory at Berlin.

Mathematics and its History was the theme of the address of the vice president of Section A, American Association for the Advancement of Science at the St. Louis meeting. It was delivered by George Bruce Halsted, and a prominent feature in it was the modern geometry.

Remarkable Effect of an Aurora Borealis upon an Electro-magnetic Clock.—In A. N. 3932 Dr. Ernst Hartwig writes of the influence of an aurora borealis, on the night of Oct. 31, 1903, upon an electro-magnetic clock in his study at Bamberg. The pendulum of the clock receives an electro-magnetic impulse from two accumulator cells every minute and, when the cells are in order, has a constant rate through the year. On this night, however, the pendulum was accelerated in an extraordinary manner, as if the accumulators were over charged. On the morning of Nov. 1 Dr. Hartwig found the clock violently disturbed, the pendulum striking on both sides of the case, and the hand pointing several hours and perhaps over a whole revolution ahead, while because of the too violent swing several seconds-intervals were skipped at a time. The accumulators had not been charged for several days past, so that it must have been an earth-current resulting from the aurora which produced the disturbance.

M. O. Callandreau.—It is but a short time since one read in the *Bulletin Astronomique* the words of generous appreciation and sympathy with which M. Callandreau committed to the grave the remains of his friend and colleague, M. Prosper Henry. There was no suspicion then that in a very short time his own funeral oration would have to be spoken, or that the staff of the Paris Observatory was so soon to suffer another almost irreparable loss by the removal of another zealous officer equally renowned, equally devoted to the interests of the observatory, but adding to its reputation in a very different direction.

For many years attached to the service of the observatory, M. Callandreau took part in the routine observations, more especially confining himself to the extra-meridional work. Small planets, comets, double stars, each in turn came under his notice, but though a skillful and painstaking observer, he will not be remembered for his diligence in this direction.

Trained in a school directed by profound mathematicians, in which, perhaps, the influence of Gylden can be recognized, and gifted with an unusual analytieal skill, he attacked nearly all the questions of celestial mechanics, and everywhere left traces of his powerful and inventive mind. His acquaintance with all the resources of analysis as applied to the practical needs of asrronomy enabled him not only to improve the methods employed in some of the more recondite applications of mathematics to astronomical problems, but induced him to open up new paths of inquiry, which are likely to exercise no inconsiderable influence on many questions of abiding interest and prime importance. It will be sufficient here to refer to his method of treatment of definite integrals which occur in the calculations of planetary perturbation, to the consideration he gave to the troublesome question of perturbations of small planets in which the mean motion is nearly commensurable with that of Jupiter, to his occasional references to the theory of the Moon, to the figures of the planets, to problems in geodesy, to show how wide an outlook he possessed over the necessities and the difficulties of mathematical astronomy. It is perhaps in some measure to be regretted that

his attention wandered over a variety of inquiries, for if everywhere he illuminated the subject under discussion, greater concentration in a particular subject might have added to his reputation and left a deeper mark on the history of his time. Perhaps his "Contributions to the Theory of Cometary Capture" comes nearest to a complete treatise, and his services in this department of astronomy will be long remembered. Some of his papers bear marks of being suggested by his professional work in connection with the École Polytechnique, where he occupied the chair of astronomy. His life was a busy one, divided between his duties at the observatory and his professorial engagements, while his kindness of disposition induced him to give willing assistance to those who applied to him. The writer of these few lines gratefully acknowledges more than one kindness he has received at the hands of this distinguished mathematician and astronomer.

Member of the Paris Academy of Sciences and honored in his own country and among his colleagues, we look in vain for his name among the foreign associates of the Royal Astronomical Society. The kind of work on which he concentrated his attention does not appeal to a numerous class of astronomers, especially would it fail to collect the suffrages of amateurs. But those who read his numerous papers will admit the ability by which they are distinguished and the informing character of their contents. We extend a respectful sympathy to the institution that is bereft of his services, to his colleagues who lose an illustrious example, and to his pupils who are deprived of an able and encouraging teacher.—*Nature*, March 10, 1904. W. E. P.

The Croatian Philosophical Society in Zagreb (Agram), which is devoted to Natural Science among the Croatian people, and was founded in 1887, has organized an astronomical section with the purpose of cultivating that science and popularizing it among the Croatian people. In furthering this project an astronomical observatory has been built at the capital of the kingdom of Croatia, Zagreb, which was ready for use Nov. 1, 1903, and is under the directorship of the undersigned.

The observatory occupies an ancient tower of 16m. in height, with an area about it of 121 sq. m. The instruments consist of an equatorially mounted refractor of 6.4 inches aperture and a smaller one 4¼ inches; both are by Reinfelder & Hertel, the larger equatorial having clock-work. Besides these telescopes there are two other instruments of 4.2 inches clear aperture viz, a refractor by Steinheil and a reflector by Fritsch, both with equatorial mounting.

The work of the new observatory is to be on the Sun, the Moon, the planets, variable stars and colored stars. Observations will be published in the Journal of the Society: "Glasnik hrvatskoga naravoslornoga drustva" which will appear twice a year, in the months of July and December. It will receive and contain articles and notes in Croatian, Latin, English, French, German, Russian and Italian.

The Director of the Astronomical section solicits the exchange of certain publications and the following address for his own: "Astronomijski observotorij naravoslovnoga drustva" Zagreb, Popv toranj, Croatia.

PROF. DR. OTTO KUCERA.

Publications Received.—The following is a list of some of the publications received recently:

Greenwich Magnetic and Meteorological Observations, 1900.

Greenwich Spectroscopic and Photographic Results, 1900.

Greenwich Astronomical Results, 1900.

Annals of the Royal Observatory, Cape of Good Hope, Vol 11, pt. 3. Occultations of Stars by the Moon, 1881 to 1895.

Observations of the Sun, 1894 and 1895, Odessa.

A full set of Meteorological Observations from Lyons, France, for 10 years.

Volumes V, VI, VII of the Photographic Catalogue of the Heavens, containing rectangular coördinates in zones respectively, $-1°, +1°; -2°, 0°; -3°, -1°$ and $0^h, 6^h 56^m; 0^h, 4^h 28^m; 0^h, 6^h 8^m$. Observatoire d'Alger.

Observations during the year 1902, Meteorologic, Magnetic and Seismatic, at Pola.

Magnetic Observations, Central Magnetic Observatory, Mexico.

Determination of Azimuth and Latitude by M. Rajna.

Vol. 51. The Photographic Atlas of the Moon, Wm. H. Pickering.

Meridian Circle Observations of Eros and Comparison Stars, Harvard College Observatory.

Meridian Circle Observations of Nova Persei No. 2 and Comparison Stars, Harvard College Observatory.

Distribution of Stars, Harvard College Observatory.

Intensity of Atmospheric Lines in the Solar Spectrum, Harvard College Observatory.

Observations with the Meridian Photometer, 1899-1902, Harvard College Observatory.

Geographical Position of the Arequipa Station in Peru, South America, by Winslow Upton, Harvard College Observatory.

Observations at Blue Hill Meteorological Observatory, Harvard College Observatory.

Publications of the U. S. Naval Observatory, Second Series, Vol. V. Meteorological Observations and Results, 1893-1902.

Publications of the U. S. Naval Observatory, Second Series, Vol. III. Eros and Reference Stars, Zodiacal Stars, Prime Vertical Observations, 1883-1884.

Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich.

Southern Circumpolar Researches, Part I. Heliometer Triangulation of the Southern Circumpolar Area.

The Law of Contraction of Gaseous Nebulæ.—In the Transactions of the St. Louis Academy of Sciences, Vol. XIII, No. 5, Professor Francis E. Nipher discussed the law of contraction of gaseous nebulæ, by the aid of mathematical analysis. We only have space, now, to give the concluding paragraphs of this interesting paper. They are as follows:

"The conditions here discussed, may perhaps be brought about in some such way as this. An infinitely diffused mass of gas occupies an infinite space. It is surrounded by an infinite series of infinite spaces, having perhaps an increasingly higher order of magnitude. A great meteorite, or a world, strays into the nebula, and probably sets it into rotation. The nebulous mass gravitates towards the solid nucleus, which has been already slightly warmed by frictional contact with the diffused gas. As the gravitating action continues, the temperature rises, and the solid mass, while still remaining solid, becomes also a liquid and a gas. The bounding surface between solid and gas has disappeared. How else

can gaseous pressure develop in an infinitely diffused mass of gas having a temperature at which all gases are solid?

"This pressure thus developed, is automatically applied in a perfectly definite way, as radiation aud contraction proceed. If, as the temperature rises, the heat radiates more and yet more rapidly, the operation is thereby hastened, but the law of contraction remains unchanged. The relations between P, δ, and T must remain invariable.

"These equations are now in condition to be linked with the solar radiation constant, and the time element. They may thus serve to permit a re-examination of the history of the evolution of the solar system."

BOOK NOTICES.

Taylor's New Plane Trigonometry.—Professor James M. Taylor, of Colgate University, has prepared a new book on Plane Trigonometry. It is published by Ginn and Company, Boston, Mass. The text is reasonably full of well-chosen matter, compact in form, with answers to problems in last pages, and all within a compass of 171 pages. The copy before us is not supplied with the ordinary trigonometrical tables.

The author's aim, well carried out, has been to prepare a text-book that shall be clear, concise and practical, yet thoroughly scientific, with proofs that are simple, direct yet fully rigorous. He uses directed lines and trigonometric ratios and gives to these fundamental ideas in trigonometry the prominence really due to each of them individually and relatively. It is important that a student from the beginning get a clear idea that directed geometric lines are measured by ratios in terms of trigonometric symbols.

The distinction between identities and equations is emphasized in definition, treatment and notation and attention is called to the reciprocal pairs of ratios in a way to fix in mind these useful relations in ordinary work. The formulæ are in heavy-faced type, and the proofs leading to them are made geometrically general according to the best usage.

The exercises are abundant and seem to be well-chosen, although this we can not be sure of without a sufficient test of them in the class-room. The geometrical figures are neatly drawn, clearly lettered and generally are satisfactory to the teacher's experienced eye. This fact has value in training the mind for finished work, in the student's preparation, his class-room work and his habits of thinking and doing.

We are sorry to see in so good a book generally, some blemishes. Why will some good mathematicians persist in writing fractions with numerator and denominator on the same line, with an inclined line between them, instead of writing the numerator above, and the denominator with a horizontal line between them? That way of writing a fraction in arithmetic, algebra or trigonometry is both inelegant and inaccurate. In our judgment it is a pure commercialism that teachers ought not to tolerate. Its inelegance is too often seen in the written exercises of students and its inaccuracy is obtrusive in oral explanations in the class-room.

The seventh and eighth chapters which treat of periods, graphs, important limits, computation of tables, hyperbolic functions, complex numbers and De Moivre's theorem are instructive and very attractive parts of this new book, for the student who wishes to go a little further than the elementary line of work previously given.

Plane and Solid Geometry by Sanders.—The author of this new text-book is Alan Sanders, of the Hughes High School, Cincinnati, O. The publishers are the American Book Co., New York, Cincinnati and Chicago.

The leading features of this text are the omission of parts of demonstrations, the introduction, after each proposition, of exercises bearing directly upon the principle of the proposition, all constructions such as drawing parallels, erecting perpendiculars, etc., are given before they are required to be used in demonstrations; exercises in Modern Geometry; and propositions and their converses.

In the construction of figures the added lines for the sake of proofs are made lighter than the outlines of the principal figures and variety of construction is prominent. The matter of the text is abundant and varied. In the hands of a competent teacher it will be suggestive and resourceful. Classes not fortunate in having an experienced teacher might go wild in the use of it, because so much depends on the teacher.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the tenth of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

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Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. Appropriate blanks have been prepared and will be sent out generally to secure this important information. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

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DR. D. K. PEARSONS.

Popular Astronomy.

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PRESENT KNOWLEDGE OF THE SUN.

W. W. PAYNE.

The interest in the study of the Sun and the observation of it were never so great and so varied as they are at the present time. A large number of amateurs with small telescopes observe the Sun daily when possible, and with pencil or crayon sketch the spots and faculæ on the projected image for useful records. Observers provided with apparatus suited to solar photography, on every clear day, get pictures of the solar surface that show spots, some faculæ and somewhat of the granular structure, if the exposure is short enough and well-timed for light and atmospheric waves.

But the most unique and probably the most suggestive mode of photography yet applied to the Sun is that which is known as the spectrographic method. The instrument for this kind of work was invented by Professor Hale and M. Deslandres almost simultaneously. Its chief working part is the double slit by means of which solar pictures may be taken in monochromatic light given by any particular chemical element in the solar spectrum that has actinic power enough to do the desired work. Calcium light is intensely strong in the photosphere and the chromosphere of the Sun. This light also has abundant actinic power which is highly efficient in photographic effect; consequently it has been chosen, in recent years, for spectrographic pictures of the Sun and its surroundings with new and remarkable results.

If photographs of the Sun are taken in the ordinary way, even when the telescope is corrected to a photographic focus, the faculæ appear on the negative only in the regions of spots, or in places of unusual solar activity, or near the limb of the Sun. But the fact that they appear so generally along the edge of the Sun led astronomers to believe that they were common to all parts of the surface, but that the glare of the stronger light in the cen-

tral regions covered them up so much that ordinary photography could not get them.

By the spectrographic method pictures show faculæ not only all over the solar surface at the same time, but they also easily and clearly distinguish those portions of the photosphere where the greatest solar activity is going on. By this new method it is also possible to photograph the regions of the chromosphere including the prominences, as they appear on the limb of the Sun throughout its entire circumference, all at once, so that a momentary condition of the Sun and its surroundings may now be obtained to a degree of detail that is wonderful, and that has been hitherto wholly impossible. From this brief description it should not be inferred that the new instrument is entirely satisfactory, or that it can not be improved, or that its possibilities have been reached. On the contrary it is more probable that only the beginning of its usefulness has yet been made. Other of the varied uses of photography, as a present means of obtaining knowledge of the Sun will appear later on, in connection with the consideration of some of its prominent features that now occupy the attention of astronomers in different parts of the world.

The oldest, most important, and most difficult of the problems which the study of the Sun furnishes is its distance from the Earth. That distance is called the unit of distances in the solar system, as the mile is regarded generally the unit for terrestrial distances. This solar unit is commonly found by obtaining, in many different ways, the parallax of the Sun itself, or that of some one of the planets favorably placed in regard to the Sun and the Earth for precise observations of its own position among neighboring stars. Formerly the planets Venus and Mars were chosen for this kind of work; but the irradiation and the brightness of the former and the phases of both have made results uncertain to an unsatisfactory degree. In the latest work some of the minor planets have been preferred, notably that of Eros, because of nearness to the Earth and its star-like disk for exact observation. The two, independent and rival methods in this instrumental field of severe requirement are, the visual telescope with the micrometer, and the photographic telescope with the sensitive plate. The large, visual telescope and the micrometer in the hands of experienced observers will doubtless give results in the work on Eros that will command great confidence, if instrumental errors shall be cared for completely and most rigorously. But the photographic method is yet too new for any one to say much about it, in the way of foretelling the degree of accuracy to be looked

for in final results for parallax. Those who have depended on this method entirely, are in a position somewhat like the astronomers who first tried the sensitive, photographic plates in the total solar eclipse of 1889. Because such plates had not been before exposed in total eelipse shadows, no one knew how to time them very certainly, especially since the shadow is a very variable quantity anyway; so, as was thought probable, this first photographic work was not very useful. The photographic work for the parallax of Eros will not prove weak in the same way it did in 1889, for astronomers know how to expose plates well and certainly, even in the trying circumstances of a varying eclipse shadow. No such trouble arises in taking photographs of stellar regions now, but the main difficulty in securing negatives of Eros and its neighboring stars for measurement of place at known times of exposure has been the identification of the faint planet and the chosen reference stars when the field was crowded with small stars. Another condition of uncertainty which some astronomers have felt in the work of preliminary reduction of the photographs has been the use of different methods. The results obtained from these different methods are not identical, the difference may be negligible apparently, and possibly, certainly so. That is the real question, for those that adhere respectively to the different methods claim one only is right, and the opponents have not yet shown to the satisfaction of all that the different ways involve only negligible error. If this had been done, there could be no real ground of discussion, and all uncertainty in this regard would disappear.

In the March number of this publication Dr. H. C. Wilson contributed an extended article in which some of these points were considered, and the method of determining preliminary results for the parallax of the Sun, by the photographic method as applied to the planet Eros, were quite fully discussed and plainly stated that the mathematics used might not prove a hindrance to popular readers. The result of this preliminary work, given in the last paragraphs of that article is 8″.802, the same as that obtained by Dr. Gill of the Cape Observatory in 1889, from heliometer measures of the asteroids Victoria and Sappho. This particular work by Dr. Gill has been rated by Professor Simon Newcomb, in comparison with eight other methods of determining the solar parallax at 5 while the

	Parallax.	Weight.
Motion of the Node of Venus........................	(8″.768)	is 10
Parallactic Inequality of the Moon...............	(8 .794)	" 10
Miscellaneous Determinations of Aberration	(8 .806)	" 10
Pulkowa Constant of Aberration 20″.492....	(8 .793)	" 40

It certainly is not discouraging to have a preliminary result from a single station, come out apparently so well. If Newcomb is right in his chosen weights for different methods of obtaining the solar parallax, the photographic method promises well for definitive results, unless some unforeseen trouble shall arise in the combination of many independent results from so many different sources.

The next problem of engrossing interest that now confronts the astronomer is the constitution of the Sun. Professor C. A. Young of Princeton University, and author of Young's series of text-books in astronomy, gave his opinion on the main features of that problem, in the leading article of the April number of this publication, page 221, Vol. XII. That statement has been so carefully prepared, and it so well summarizes, in the border land of fact, our present knowledge of the constitution of the Sun, that every interested reader will peruse it very thoughtfully; and because of it many will want more information in detail that supports such definite views which their author has expressed with becomingly modest reserve. Much information of this kind will be found in a recent book, titled, "Problems of Astrophysics," by Agnes M. Clerke and published by Adam and Charles Black, of London, 1903. We do not know of any other single source for so much of such information, in the English language, as this remarkable book furnishes. It is written in popular language, and it presents preliminary results in astronomical work now in progress along the whole frontier line of solar science with such insight and fidelity, as to indicate rare practical judgment in weighing evidence for generalization, and in drawing conclusions which have theoretical value.

In a brief survey of the field of present activity, it is an interesting study to notice the lines of progress in solar physics and the methods employed in pursuing them. It long has been believed that the key to the situation that will reveal much concerning the constitution of the Sun is a better and a fuller knowledge of sunspots, and systematic work in this direction has been in some degree successful during the last score or two of years. For we now know of the periods when sunspots are most and when they are least, and how these spotted regions curiously move, north and south, over the solar surface; we know of the relation of these spot periods to any similar magnetic activity on the Earth's surface; we know of the apparent make-up of sunspots, their changes, continuance and destruction, of the tremendous activity of the solar surface in regions about them and

something of the granular and facular structure of the solar surface generally; we know of the reversing layer, the smoke stratum, the chromosphere and the prominences streaming up from its upper regions, their constitution in part, and their evanescent and changeful forms that tax the ingenuity of experts to copy or record in any definite way; we know of the rotation of this vast solar body; and we know something of the beautiful and that most wonderful halo around the Sun, the corona, that flashes out in such richness of color, and in such variety and delicacy of form everywhere, when the Moon hides the face of the Sun in a total eclipse.

This knowledge and much more like it in detail we know about, and we have it on record for the use of science generally. But there is infinitely more immediately connected with all these things that we do not know. We do not know anything certainly about the interior regions of the Sun, the state of the matter therein contained, its mode of activity, its temperature, its relation to all that great variety of surface phenomena within the range of human sight aided by the telescope; or to that array of physical conditions recorded by the spectroscope on the one hand, or to that which is revealed by the bolometer on the other in the vast and fruitful field that is uniquely its own in the more recent studies of the solar temperature. We do not know the cause or causes of the sun-spots, their periodicity, their drift, their level; why magnetic activity on the Earth should correspond with their own, where the reversing layer is exactly, and certainly what it is; why the faculæ and the prominences are everywhere on the Sun's surface, and spots only in limited areas; what the solar corona is, how to observe it when the Sun is not eclipsed, the cause of its complexity and its matchless beauty, its extreme rarity and its broad extent,—these questions and others like them and still others beyond them that astronomers do not know anything of, except in vague suspicion, are waiting for answer in some distant future time.

Before we close this brief sketch, we ought to refer to some of the splendid work that is now going on in different parts of the world to increase our knowledge relating to some of these questions, and to indicate, as far as we can the degree of success that is being realized.

The chemistry of the Sun is one of the most general and one of the most important branches of solar science that is now being prosecuted. Advance work in it began with the appearance of the Rowland photographic map of the solar spectrum. Something

of the appalling task that this map put on the shoulders of scientists, in the outset, is seen in the fact that Professor Rowland spent years in the measurement of its lines, and in so much time did not identify more than 20,000 of them, in place and atomic weight, in definitive way. If we remember that between the lines H and K, in the violet, there are 150 absorption lines to be measured it is easy to see that a photographic map several hundred feet long would furnish work in this one particular almost endless in amount. But still it is encouraging to know that the persistent work of Rowland and others have made certain the presence of thirty-nine elements in the Sun known to our terrestrial chemistry, which are represented in the solar spectrum by few or many lines, as the individual elements seem to be simple or complex in their molecular motions. One has only to think a moment about the elemental structure of iron to be amazed at a molecular condition that should make, in the solar spectrum, more than 2700 line coincidences, every one of which has supposedly a different meaning, and every one of which is probably necessary somehow to fulfil the office of iron in the natural world.

From such facts as these any one can infer something of the scope of molecular physics opened to view by the spectroscope, and anticipate some of the difficulties to be met and overcome in every direction that safe and certain progress may be possible.

It is then proper to ask how much really has been done during the last few years to unravel this maze of complexity in the interest of definite knowledge about the chemistry of the Sun?

We think it is safe to answer that much has been accomplished by the aid of the modern powerful spectroscope whose work can now be recorded by the sensitive photographic plate. One general result from this source seems to be that leading spectroscopists are coming more and more to believe in the fundamental unity of the chemistry of the Sun and that of the Earth, which, if true, is a long step forward in the progress of the new astronomy.

Space now forbids that we speak more in detail of the solar spectrum, of the reversing layer, of new elements, more fully of the photosphere and its dusky veil, of some phases of sun-spots and their spectra, of the Sun's rotation and of the solar cycle. Later we hope to do so.

KEPLER'S ATTITUDE TOWARDS ASTROLOGY.

F. A. TONDORF, S. J.

FOR POPULAR ASTRONOMY.

Writers on matters exegetical and astronomical alike have often spent themselves in offering to the public what seems to them a plausible explanation of the star which guided the Wisemen to the crib of Bethlehem. To sit in judgment on the success of their efforts would quite exceed the limits we have set for ourselves in the present paper. Suffice it to note that these writers, with but few exceptions, have all insisted that they found in the writings of the immortal Kepler sufficient evidence of a settled opinion. They bid us to recall that our scientist was a contemporary of, and in close communication with the celebrated Danish astronomer, Tycho Brahe. Now Tycho's star of 1572 was, it is said, identified with the guide of the Magi. Hence they conclude, with what logic we know not, that Kepler was in sympathy with this theory. Nor is this all. They appeal to Kepler's account of the star of 1604. October of that year revealed the presence of a new heavenly body within less than a degree of the planets Jupiter, Saturn, and Mars, then in conjunction. Our Wurtenburg sage, informed by his assistants, Schuler and Brunowsky, of the appearance of this strange intruder, set himself to the task of filling out the pages of his astronomical record entitled Nova Serpentarii. Careful computation led him to the conviction that a similar conjunction had occurred in the years 747 and 748 A. U. C. Now this was just about the time of the first Christmas. What then was his conclusion? We prefer to anticipate others here by quoting Kepler's own words: "The star (i. e. of the Magi), which two years before had begun to shed its light, beat its way into the very neighborhood of the great conjunction of Saturn, Jupiter, and Mars, in the thirty-ninth Julian year, and was in consequence very like to our modern visitor."* We find him expressing himself in like terms to Joannes Barwitius in a letter dated Prague, Sept. 6th, 1606. "It follows then that the star, which led the Magi to the crib of Christ, though preceeding the birth of Christ by two years, was on this account (i. e. the conjunction of the three aforesaid planets) comparable to our star (i. e. the Nova Serpentarii.") But the writers before referred to would have it otherwise. Not only, say they, did Kepler admit that there was a similarity, but he maintained that the two stars were identical throughout. We beg leave to hint

* Kepleri Opera Omnia, Ed. Frisch, Vol. II. p. 709.

(1) Frisch, vol. IV, p. 177.

at the reasons suggested by Dr. Ideler, an authority freely quoted in this connection. According to him, presumably because a miracle was ever to be taken as an impossibility, Kepler held that the star was naught save a natural phenomenon. Now the one tenable explanation of the marvellous effects attendant upon this sign lay in the theories of the Chaldean astrologists. Kepler then was ready to embrace it. Why? Because Kepler was a believer in astrology. That this last proposition is scarcely admissible is the object of the present paper. We are quite ready to admit that even to the day of Kepler, the terms astronomer and astrologer were synonomous. Babylonian superstitions still held sway. But we find little reason here why our "watcher of the skies" should not have quit the beaten path. However, to do so absolutely would have been to jeopardize his position as mathematician to the imperial court. That he would have liked to do so, is not difficult to gather from his letter to Herwart, written on September 9th, 1599: "Framing calendars and unfolding the horoscope are to me a veritable but necessary slavery. But of what avail would it be to me to forego it; a momentary freedom would but usher in a worse servitude. In order then not to forfeit my regular income, position and title, I accommodate myself to the folly of an inquisitive mob." (2).

In plying his art our diviner found himself, for the most part, the child of good fortune. A single instance will go to show this. General Albrecht von Wallenstein, through the medium of a mutual friend, approached him for an account of his horoscope. Kepler's prognostication tallied quite exactly with what afterwards took place (3). This will appear the more remarkable when it is remembered that the identity of his subject was concealed from him (4). That Kepler had his days of failure too, is sufficiently attested by the following. A son was born to him Feb. 2nd, 1598. The father thus foresaw his future: "Constellationes largiuntur ingenium, nobile, corpus, digites, manus agiles, mathematicis et mechanicis artibus aptum. Luna in □ ♄ imaginativam vim fortem, industriam, suspicionem, tenacitatem, ex utraque curæ, profundæ cogitationes, devotio, miseratio, tristitia—anmuetig.—Ascendens in □ ☉ adjuvat illa, et cum luminosiore ♎ australis in ortu, pertinacem et indomitum significat et magna suscipientem." (4) A letter under date of June 11th of

(1) Ideler Handbuch der Mathematischen und Technischen Chronologie BD. II, S. 400 ss.
(2) Frisch, vol. I, p.
(3) Ibid, p. 390 ss.
(4) Ibid, p. 386 ss.
(5) Ibid, vol. VIII, p. 699.

this same year tells Maestlin the vanity of it all, for two short months after the birth of the child it died. (1).

We are now led to ask whether Kepler was in sympathy with his science. This we can hardly believe of one who was forced into it by purely mercenary motives. We have seen above that he was actuated by such motives, but it may not be amiss to enter on the subject here. In the year 1601 Tycho Brahe succeeded in persuading the Emperor Rudolph to assign him as assistant, Kepler, whose duty it became to prepare a new set of astronomical tables, to be known as the Rudolphian Tables, intended to supercede those calculated upon the Ptolemaic and Copernican systems. His Majesty had pledged himself to meet all the expenses of the undertaking, and Kepler, to whom was alloted the task of examining the observations of Mars, threw himself heart and soul into the work. The untimely death of Tycho suspended matters, and from this on Kepler found himself in financial straits. Humiliating though he found it, he was forced to betake himself to casting nativities, in order to eke out for himself and his family the means of subsistence. He excuses himself in a note to Wacker, saying that he considers this a far more becoming occupation than that of a mendicant. (2) A man of his intellectual attainments could not but see, from the very outset that he was treading on dangerous ground. He was not blind to the fact that a guess at its best must remain a guess; and so, lest his reputation should suffer early shipwreck, he was always careful to append some saving clause to his prognostica. In the light then of the above are we to interpret the motto sent his friend Eckhardt:

> "Freund Echardt, lasz das Klügeln sein,
> Witz ist Frau Furwitz Tochterlein,
> O Sorgen gross, O Nützen Klein." (3)*

Wonderful, indeed, was the transformation which a few years of practice effected in him. Diffidence gave way to confidence, infallibility in his predictions superseded mere conjecture. Sharp rebuke is the lot of those who dare to question the trustworthiness of his auguries. Witness hs letter to the worthy astronomer Fabricius: "O you poor, unfortunate son of man! Have my prophesies so far failed to dispel your fears that you seek refuge in prayer to ward off the misfortunes which you fear may steal upon you?" (4)

(1) Ibidem.

(2) Frisch, vol. VIII, p. 845.

(3) Ibid, p. 348. * Echardt, pry not into mystery,
Knowledge born of curiosity
Brings much care and little good to thee.

(4) Frisch, vol. I, p. 356.

Now whence this confidence, may we ask? Are we to take it as the product of a more mature judgment? This we could readily admit, were we not in consequence brought face to face with difficulties which such passages as the following suggest: "Astrology is in very truth the foolish lttle daughter of Mother Astronomy" (1): "Your error is one common to the greater part of the school of doctors, who fancy that fortunes drop from the skies. Naught comes hence save light" and "you will find no wife among the stars"(2). The reason then is to be sought for elsewhere. Cato it was, we think, who is said to have wondered how two Roman augurs could meet without smiling at the credulity of those who consulted them. Had he lived in Kepler's time his wonder would have ceased in presence of the fact, for even Kepler laughed in his sleeve at the ease with which his patrons were duped. "I know not a few," he writes, playfully, "who buy all kinds of calendars to find in one that on a certain day fair weather, on another a storm is predicted. Let the elements fetch whichever they will, one must be correct. In following up such humbugs they find their daily pleasure." (3) Like passages could be quoted without end. I content myself with one more which will go to show not only that his clients were duped, but that they were parties to the fraud, if so it may be styled. Zehentmeyer, secretary of Baron von Heberstein, thus addressed himself to Kepler: "You are a man busied in scientific investigation and in reading the future in the stars. Please inform me whether those heavenly bodies indicate anything in particular regarding this section of the country. The Baron, my dear Sir, is extremely anxious to give you, a man of such authority, a say in this matter. I am far from ignorant of your conviction that nothing can be foretold with certainty, in fact that the science of astrology is a vague and treacherous art. However, you know how man hankers after news, and how he would have nature forewarn him of the future. I pray you then send me something! Harbor no fear; what you remit shall be considered strictly confidential." (4)

Supposing then that a reason may be found for Kepler's' attitude, must we still admit that he played the part of a hypocrite? The question deserves consideration. There is a familiar principle, which reads: "Scienti et volenti non fit injuria," i. e. if a man is aware of wrong you do him and consents to it, you do him no injustice. Again, our scientist anticipated little harm from his equivocal divinations. Indeed,

(1) Ibid, p. 560.
(2) Ib. p. 385.
(3) Id. vol. VII, p. 697.
(4) Frisch, vol. VIII, p. 712.

when he suspected that such might happen, he took particular care to express his mind freely. Accordingly he placed an interdict against the use of astrology in the imperial council. (1)

We rest the case here. Should our demonstration fail to convince the readers of *Popular Astronomy,* at least they will find in our article serious objections against the charge that Kepler was a sincere believer in astrology.

JESUIT ASTRONOMY.

WILLIAM F. RIGGE, S. J.

PART II. CONTINUED.

Granada, Spain.—A very fine observatory was erected two years ago in the outskirts of Granada, among the mountains and under the pure sky of Andalusia, at an altitude of about 800 meters (2600 feet) above the Mediterranean. It is built of brick trimmed handsomely with stone in the Doric style of architecture. It consists of a central portion surmounted by a dome 8 meters (26 feet) in diameter, built by Mailhat, and four wings. The northern wing is the entrance or vestibule, the eastern contains the transit and photographic rooms and spiral staircase, the western the meteorological instruments, and the southern two private rooms for the observers, while the central space below the dome is devoted to the seismical apparatus. The equatorial has an aperture of 32 centimeters (12½ inches) and a focal length of 5.35 meters (17½ feet). Outside of the objective is a "cat's eye" diaphragm which may reduce the aperture to 2 centimeters (¾ inch), and is operated from the eyepiece with an indicator dial. In order not to disturb the position of the micrometer, a mirror may be inserted into the tube near the eye end and the rays from the objective deflected into a side tube which carries a spectroscope of 12 prisms. One of the finders, which has an aperture of 10.9 centimeters (4½ inches), may be fitted with a photographic camera. There are also a meridian circle reading to seconds, a chronograph, a 16 and a 10 centimeter portable telescope, a good theodolite, an altazimuth by Salmoiraghi of Milan, a Silbermann heliostat, a Thollon prism combined with an Amici polyprism, a clock and a Roskell chronometer. The director is Fr. Juan Granero, assisted by Fr. Ramon Martinez.

(1) cf. "Himmel und Erde" 13 Jahrgang S. 207 ss.

Tortosa, Spain.—A large observatory is at present being built near Tortosa, on the eastern border of Spain and near the mouth of the river Ebro. Its main object will be the study of terrestrial magnetism, not only in itself, but also in its relation to other sciences. There are to be five principal and separate buildings devoted to the several departments. Two of these will be reserved for magnetism, the third for electrical and meteorological, and the fourth for seismic apparatus of the latest patterns. A fifth building, which is in the form of a cross, is for the study of the Sun's activity. The central part will contain a small equatorial for the observation of sun-spots and, also by means of an attached spectroscope, of the prominences. One of the arms of the cross will contain an Evershed spectroheliograph with two slits for obtaining photographs of the whole chromosphere. The second will have a photographic spectrogoniometer with a Rowland grating for measuring the velocity of the solar eruptions. The third arm of the building will house a transit and sidereal and solar clocks. The latter will synchronize all the registering apparatus in the entire observatory. The fourth will be private apartments for the observer. There will be in addition a polar siderostat, which may serve also as a coelostat.

The observatory is about two kilometers distant from a steam railway. The absence of all electric railways and magnetic disturbances, and the purity of the sky augur well for the success of the work. A large house of higher studies near by will enable many Jesuit students to become acquainted with observatory work. The director is Fr. R. Cirera, who was one year in Stonyhurst and for six years was superintendent of the magnetic department of the Manila Observatory, where he issued a large quarto volume on "El Magnetismo Terrestre en Filipinas." He expects to have all the departments of his large observatory in running order by the end of 1904. He looks forward with high hopes to the total solar eclipse of August 30, 1905, for which the very favorable position of his observatory near the central line of totality will give him most exceptional opportunities.

Zi-ka-wei, China.—The Zo-sè Observatory, near Zi-ka-wei, about six kilometers southwest of Chang-hai, China, like the Manila Observatory, owes its reputation mainly to its meteorological department. Fr. Dechevren, who was the director for many years, has won for himself a well-deserved name not only among the public in those parts, but also among technical scientific men throughout the world. He is now retired on account of age on the Island of Jersey in the English Channel, where he is

continuing his investigations in meteorology. His successor at Zo-sè, Fr. Chevalier, has distinguished himself in his astronomical, no less than in his meteorological work, for in 1901 by unanimous vote of the commission of the French Academy, he received a prize of 3,000 francs for his publications in both of these branches.

The Zo-sè Observatory is 25 meters in length. The lower floor contains Father Secchi's great meteorograph. To the left is the library of 20,000 volumes with its numerous and valuable Chinese manuscripts, and to the right there are two laboratories, while the upper story of the central part of the building is devoted to astronomy. Besides a small meridian circle there is a fine twin equatorial built by Gautier on the model of the international photographic telescopes used in constructing the star charts. Each objective is of 40 centimeters (15.7 inches) aperture. The focal length of the photographic one is 6.87 meters (22.54 feet), making one minute of arc equal to two millimeters of length on the plate, but the focal length of the visual objective is somewhat greater. Quite a number of photographs have been taken last year for the purpose of determining stellar parallaxes. A measuring engine has lately been acquired and begun work upon the plates. Father Chevalier is at present (January 7) alone, but is daily awaiting the arrival of an assistant.

Tananarivo, Madagascar.—The observatory of Ambohidempona near Tananarivo (or Antananarivo) is the highest astronomical observatory in the world, being 1400 meters (4600 feet) above the level of the sea, whilst the next highest, the Lick Observatory in California, is 1300 meters high. It was founded in 1889. The observatory has the form of the letter E, and consists of four circular pavilions surmounted by domes. The three principal pavilions which form the main front, lie in the meridian, the central one having a diameter of 26 feet. It is equipped with a Rigaud meridian circle and an equatorial. There are also well-equipped magnetic and meteorological departments.

Fr. Colin is the director and had begun work on a star map when the war between France and Madagascar drove the Jesuits from the island. The observatory was plundered and demolished by the natives who imagined that on account of its high and commanding position it would be made a fortress by the enemy, and its instruments converted into engines of war. The friends of the institution succeeded in saving a few of the principal instruments. The French had scarcely become masters again, when the stolen instruments were in part at least returned. Later

on the restoration of the observatory at government expense was decreed. The French Academy has named Father Colin an Officier d' Academie and de l'Instruction publique and a corresponding member of the Academy. He has rebuilt the observatory, and at the invitation of General Gallieni, is now engaged in determining the geographical position of the principal roadsteads or anchoring places on the southwest coast of the island.

Quito, Ecuador, South America.—From 1870 to 1875 the Jesuits had charge of the government observatory. While they were equipping it with suitable instruments, the political disturbances which culminated in the assassination of President Garcia Moreno in 1875, drove them from the country.

The following observatories I class as student observatories, their primary purpose being educational.

Calcutta, India.—The meteorological astronomical observatory of St. Francis Xavier college was founded by Fr. Lafont who received some subsidy from the government. At the request of Marquis Dufferin, formerly viceroy of India and later British envoy at Paris, he was raised to the rank of Officier d'Academie by the French government. He was also a Fellow of the University of Calcutta, and in 1880 received the medal of the Indian Star.

The present director is Fr. Francotte. He was one of a company of nine Jesuits and ten assistants who, under the leadership of Fr. C. De Clippeleir, observed the total eclipse of the Sun of January 22, 1898, at Dumraon, Behar, India. Their instrumental outfit consisted of three photographic cameras of various focal lengths, a prismatic and a grating camera, and 3 and 4 inch telescopes, a chronograph, etc. Their results were published in a book of 104 pages and 14 plates.

Bulawayo, Rhodesia, South Africa.—A transit instrument lent by the Royal Astronomical Society of England, a clock, a set of chronometers and a chronograph form the nucleus of an observatory, at which Father Goetz intends to make observations of variable stars and extend Fr. Hagen's Atlas to the south pole, as soon as he can secure the necessary telescope. The meteorological and magnetic departments of his observatory are well equipped. The government has granted the site and given some financial aid.

At *Oña, Spain*, the college of St. Francis Xavier has an 8-inch telescope furnished with 11 eyepieces, a 4¼-inch transit, several clocks, a marine chronometer, a sextant, etc.

At *Feldkirch, Voralberg, Austria*, a 6-inch equatorial, well provided with eyepieces and a spectrometer, will be mounted in the

course of the year.

At *Louvain, Belgium,* there are an equatorial of 6 and a transit of 3½ inches aperture, a theodolite, a clock, spectroscopes, etc.

Oudenbosch, Holland, possesses a 4-inch equatorial. Fr. Stein has published the results of his series of observations for the variation of latitude made at Leiden from June 1899 to July 1900.

Puebla, Mexico.—The college of the Sacred Heart has a small transit and a 6¼ inch equatorial.

Habana, Cuba.—The Colegio de Belen possesses a 6-inch Cooke equatorial, a projection apparatus for observing sun spots, a Mc Lean stellar spectroscope, a Troughton theodolite, a sextant, and minor instruments. The best scientific attention of the college, however, is centered in its excellent meteorological observatory, which is abundantly equipped with all modern instruments and has already won great distinction, especially under Father Viñez.

At *Woodstock, Maryland,* there are a 3-inch equatorial, a 3-inch portable transit, a chronograph, clock, chronometer, sextant, etc.

At *Prairie du Chien, Wisconsin,* from 1884 to 1888 Fr. Hagen used a 3-inch equatorial under a 12-foot dome for observing variable stars. The results were published in 1901.

St. Louis, Missouri.—The St. Louis University has no observatory at present, but at its former location from which it was driven by the encroachments of business in 1888, there were two domes* devoted to a small transit and a 6-inch telescope. There are in addition a 3-inch equatorial, a grating spectroscope, a position micrometer, a reflecting circle, several quadrants, a clock, etc.

Omaha, Nebraska.—Creighton University possesses a 5-inch equatorial, a 3-inch meridian circle reading to tenths of a second, a chronograph, a chronometer, an altazimuth, clocks, etc.

St. Mary's, Kansas.—St. Mary's College has a 3½-inch equatorial.

At *Santa Clara, California,* an 8-inch equatorial is permanently set up in a garden under a house which can be rolled away on wheels. There are also a position micrometer and an unmounted 4-inch equatorial. A meteorological department has more than run apace with the astronomical, and is well equipped.

Montreal, Canada.—There is at present no observatory in Can-

* Built in 1855. The University was founded in 1829.

ada, but the interest taken in astronomy is evinced by the fact that Fr. Garaix, assisted by other young Jesuits, personally ground, polished, silvered and mounted in a 12-foot paper tube a 20-inch mirror, the third in size in America.*

Instrumental Inventions.

In instrumental inventions the Jesuits have not been idle. I will call attention only to the most important ones.

It is well known that experienced observers may differ as much as half a second or more in noting the exact moment at which a star crosses a thread in the telescope, and that even the estimate of the same observer is subject to considerable variations. Hence "one of the most important problems of practical astronomy now awaiting solution is the contrivance of some practical method of time observation free from this annoying human element, the personal equation, which is always more or less uncertain and variable."† Two Jesuits have attempted solutions of the problem.

The first was proposed by Fr. Braun of the Haynald Observatory, Kalocsa, Hungary.‡ The method consisted in moving a thread by clockwork with the same speed as that of the star to be observed, thus practically changing a moving object into a stationary one. When the thread had been accurately set upon the star by the micrometer and then the chronograph circuit closed by the observing key, the readings of the micrometer and of the chronograph determined the moment of the star's transit across the thread and the distance of the latter from the instrumental meridian. As Fr. Braun could not find a mechanic in Kalocsa to execute this design, and as circumstances did not allow him to do it himself, this transit micrometer was never tested in actual practice.

Repsold took up the same idea, but omitted the clockwork movement of the thread as too complicated, and substituted a movement by both hands. This proved to be unsatisfactory. Struve in Königsberg, probably not knowing of Fr. Braun's idea and seeing only the Repsold form of the instrument, then reinvented the clockwork attachment as an improvement, and tested its performance in an extended series of trials. Without wishing

* The Scientific American, Jan. 24, 1903, gives the details of the process along with several illustrations.

† Young's General Astronomy, first edition, 1888, page 77

‡ Berichte von den Erzbischöflich—Haynaldschen Observatorium zu Kalocsa in Ungarn. Münster i. W. 1886, page 163.

in the least to detract from the credit due to other inventors and experimenters, it is only proper for me to refer to Fr. Braun's priority in the matter.

The second method of eliminating the personal equation in transit observations was devised by Fr. Fargis, of Georgetown College Observatory, in 1891 as an improvement upon the one with which Professors Pickering and Bigelow had been experimenting. This method makes use of photography, and consists in pressing a photographic plate against the reticule, or rather against a plate of glass on which only one thread or line, the instrumental meridian, is drawn, and that too only at its ends. The rays going to form the image of the star on the plate are intercepted by a light and narrow metal tongue attached to the armature of an electro magnet. As the clock breaks (or makes) the circuit, say for one-tenth of a second at every second, this tongue is raised for that interval, the star's light falls on the plate and there makes an impression. The plate therefore will contain a series of dots one second apart, one or more, of course, being omitted each minute for the sake of identification. When the transit is over, a flash-light outside of the objective impresses the instrumental meridian line on the plate, which then contains a self-recorded transit in its entirety. The microscope next measures the position of as many star images as are desirable relatively to the fixed line, and furnishes in this way even the value of one revolution of its own screw. The performance of the photochronograph in actual practice has verified all that was expected of it, as may be seen in Fr. Hedrick's discussion of the transits of 161 stars observed on 15 nights.* A unique 9-inch photographic transit, with photographic collimators, has been mounted for some time at the observatory. Circumstances have hitherto prevented its systematic use.

The photochronograph has also been seriously tested in the zenith telescope. Three forms of this instrument have been used at Georgetown. In the first, set up in 1893, the telescope was floated on a basin of mercury. In the second, invented and used in 1894 by Fr. Algué, now director of the Philippine Weather Bureau, two telescopes were mounted in the same tube with their objectives at the opposite ends and their foci coinciding. The light from one star of a latitude pair came directly through one of the objectives to the photographic plate, while that of the other was first reflected from a basin of mercury before passing

* Photographic Transits of 161 Stars, Washington, 1896.

through the other objective to the opposite side of the same photographic film. In this form, called the reflecting zenith telescope, a double rotating sector replaced the two separating occulting bars generally used, and even the instrumental meridian line was not drawn, as the known seconds of the transits are sufficient for this purpose.

The third form of zenith telescope was the usual visual one, except that the photographic plate replaced the micrometer and four zenith levels were used. This instrument made the first complete series of photographic observations of the variation of latitude. The work was begun by Fr. Rigge in 1895 and continued and finished by Fr. Hedrick. Unfortunately, it has been impossible to complete the reductions.

Fr. Braun was one of the first to conceive the idea of the spectroheliograph for photographing the whole Sun with its spots and prominences. He gave expression to his views in the *Astronomische Nachrichten** as early as 1872, and in his Berichte of the Haynald Observatory, published in 1886, he added several improvements to his original plan. The principle of the method consisted in focussing the image of the Sun upon the slit of a spectroscope, rejecting the whole resulting spectrum except one of its most actinic lines, and allowing this line to fall through a second slit upon a photographic plate. As the first slit moved across the Sun, the second moved across the photographic plate and there built up the solar image by a succession of the same lines or chords which the first slit measured upon the Sun, these lines being interrupted at the corresponding places by spots and extended by prominences. Father Braun's spectroheliograph was never constructed. Professor Hale, then at the Kenwood Observatory, was the first to actually construct a satisfactory instrument in 1891, which while differing in details, made use of the same principle. Professor Hale gives due credit to Fr. Braun for his idea in the *Sidereal Messenger* No. 96, June 1891.

* No. 1899, and in Pogg. Ann. Vol. 148, p. 475.

(TO BE CONCLUDED).

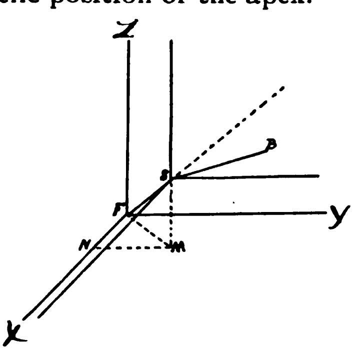
THE DETERMINATION OF SOLAR MOTION.

MARY W. WHITNEY.

FOR POPULAR ASTRONOMY.

II.

In my last paper I brought the problem of solar motion to the status reached about the middle of the nineteenth century. In 1859 Sir George Airy, Astronomer Royal, read before the Royal Astronomical Society his celebrated paper "On the movement of the solar system in space." He offered objections to the Argelander method, primary among them the necessity of assuming a point that was not known within twenty degrees or more. Therefore he proposed to treat the problem without such an assumption. As he says in the paper the method "consists in removing the primary geometrical motions from the apparent movements on a globe to the real movements in space." That is, Airy used the processes of analytical geometry instead of those of spherical trigonometry, and he made no assumption regarding the position of the apex.



Our figure represents two parallel systems of rectangular co-ordinates. F is a fixed origin and denotes the position of the Sun at the beginning of the adopted interval of time. S is its position at the end of this interval. FS, then, represents the direction and amount of the solar motion, regarded as rectilinear. The planes XY are parallel to the plane of the equator, and the axis of X is the line of equinoxes. Therefore the angle of elevation above the plane of XY is the declination of the body, and the angle which the projected distance makes with the axis of X is the right ascension. The point cut in the celestial sphere by the line FS is the apex of the Sun's way. Its right ascension NFM, and its declination SFM are our desired values.

Let A and D denote these values. Further, let *l* denote the linear velocity of the Sun, FS, and X, Y, Z the co-ordinates of S referred to F. Then,

$$\begin{aligned} X &= l \cos D \cos A \\ Y &= l \cos D \sin A \qquad\qquad (1) \\ Z &= l \sin D \end{aligned}$$

Therefore, A D and l would be known, could we determine X, Y and Z.

Let us now consider the system of which S is the origin, and for the present let us regard S as at rest. B represents any star whose distance from S is d, and whose right ascension and declination are α and δ. If x, y, z denote its co-ordinates, we have

$$\begin{aligned} x &= d \cos \delta \cos \alpha \\ y &= d \cos \delta \sin \alpha \qquad\qquad (2) \\ z &= d \sin \delta \end{aligned}$$

Suppose the star B to move. All the values in (2) would vary, and these changes can be obtained by differentiation.

$$\begin{aligned} dx &= -d \cos \delta \sin \alpha d\alpha - d \sin \delta \cos \alpha d\delta + \cos \delta \cos \alpha\, dd \\ dy &= d \cos \delta \cos \alpha d\alpha - d \sin \delta \sin \alpha d\delta + \cos \delta \sin \alpha\, dd \qquad (3) \\ dz &= d \cos \delta d\delta + \sin \delta dd \end{aligned}$$

By elimination, we find

$$\begin{aligned} \cos \delta d\alpha &= -\frac{\sin \alpha}{d} dx + \frac{\cos \alpha}{d} dy. \\ d\delta &= -\frac{\cos \alpha \sin \delta}{d} dx - \frac{\sin \alpha \sin \delta}{d} dy + \frac{\cos \delta}{d} dz. \qquad (4) \\ dd &= \cos \alpha \cos \delta\, dx + \sin \alpha \cos \delta\, dy + \sin \delta\, dz. \end{aligned}$$

The forms of equations (4) would in no wise change, if we regard S as moving from F to S, while B remains fixed. The variations in the co-ordinates of B, dx, dy, dz would then be the X, Y, Z of (1), with opposite sign, if we suppose S moving toward B, as in the figure.

In reality, the observed proper motions dα and dδ are due to the combined motions of B and S. To express this, let us place $dx = X' - X$, $dy = Y' - Y$, $dz = Z' - Z$, where X′, Y′, Z′ denote the variations in co-ordinates due to the star's own motion. Equations (4) then become, if we separate the parts arising from solar and stellar motion:

$$\begin{aligned} \cos \delta\, d\alpha &= \frac{\sin \alpha}{d} X - \frac{\cos \alpha}{d} Y + \left(\frac{\cos \alpha}{d} Y' - \frac{\sin \alpha}{d} X'\right) \\ d\delta &= \frac{\cos \alpha \sin \delta}{d} X + \frac{\sin \alpha \sin \delta}{d} Y - \frac{\cos \delta}{d} Z + \\ &\qquad \left(\frac{\cos \delta}{d} Z' - \frac{\cos \alpha \sin \delta}{d} X' - \frac{\sin \alpha \sin \delta}{d} Y'\right) \qquad (5) \\ dd &= -\cos \alpha \cos \delta\, X - \sin \alpha \cos \delta\, Y - \sin \delta\, Z + \\ &\qquad (\cos \alpha \cos \delta\, X' + \sin \alpha \cos \delta\, Y' + \sin \delta\, Z') \end{aligned}$$

The third equation is not required in the present treatment. I have developed it with others, because of its later significance.

The left hand members of the first two equations are given by observation, since now $d\alpha$ and $d\delta$ are the actual motions in right ascension and declination. The right hand members involve X, Y and Z, whose values we seek, in order to determine A and D by (1). But they also contain X′, Y′, Z′, whose effects are quite unknown. A similar difficulty presented itself in the Argelander method, but it did not there find expression in our equations, since in that case we ignored the star's own motion in constructing our figure. But the method of treatment is the same here as there. The terms containing X′, Y′, Z′ are regarded as accidental errors, to be eliminated by a least-squares solution. Therefore the final equations of Airy are:

$$\begin{aligned} \cos\delta\, d\alpha &= \frac{\sin\alpha}{d}\,X - \frac{\cos\alpha}{d}\,Y \\ d\delta &= \frac{\cos\alpha\sin\delta}{d}\,X + \frac{\sin\alpha\sin\delta}{d}\,Y - \frac{\cos\delta}{d}\,Z \end{aligned} \qquad (6)$$

Every star involved in the discussion gives two equations of the form (6). Before we apply the principle of least-squares to these equations, we must decide what shall be done in regard to the distances, d. Some assumption must be made. We may adopt any one distance as our unit, in terms of which X, Y, Z and the l of (1) shall be expressed. But the ratios of the other distances to this unit must be assumed, until that day in the future when stellar parallaxes shall be well known. Airy selected the mean distances of first magnitude stars as his unit and adopted the ratios of W. Struve, referred to in my preceding paper.

The least-squares solution of (6) will give the most probable values of X, Y and Z. These substituted in (1) will give A, D and l; l is, of course, expressed in terms of the adopted unit i. e. it is $\frac{l}{d}$, the angular motion of the Sun as seen from the unit distance.

Airy applied his new method to 113 stars, whose proper motions were large. I will group in a table at the close of my paper various values obtained by this and other methods. Airy's method was immediately and generally adopted, and it has continued the most favored process up to the present time. Only within the last few years have doubts of its efficacy found expression.

The modifications introduced since Airy's first application,

have turned mainly on the treatment of distance. Astronomers have come to believe that magnitude is not a good test of distance, because a larger knowledge of stellar parallaxes has shown that such a basis is not justified by actual values. If one examines the table of stellar parallax, magnitude and proper motion given in the appendix of Young's text-books, it requires but a glance to decide that, within the range of the table, proper motion is a surer basis of nearness than magnitude. Therefore later astronomers have inclined to rest relative distance on proper motion. Further, in some discussions the proper motions have been taken in groups, and a separate solution obtained for each group. I will give the results of such a treatment by Stumpe,* as this will bring out a point referred to in my last paper. This point was, that, if the effects of peculiar proper motion are not of the nature of accidental errors, the results may give some indication of this fact. Stumpe's solutions by groups are as follows:

	No. of stars.	Mean proper motion.	A.	D.	$\frac{1}{d}$
		$''$	$^\circ$	$^\circ$	$''$
I	551	0.23	287.4	42.0	0.140
II	340	0.43	279.7	40.5	0.295
III	105	0.85	287.9	32.1	0.608
IV	58	2.39	285.2	30.4	2.057

The values of $\frac{1}{d}$ show the greater proximity of the stars of large proper motion. The values of A do not contain greater deviations than we might expect. But the regular decrease of D for larger proper motion suggests a systematic error that cannot so easily be disposed of. Herein may lie an indication, either that the method of solution is somewhere defective, or that our assumptions are not all correct. It may mean that the peculiar proper motions of the nearer stars are not to be treated as accidental errors, that is, that the nearer stars are bound together in some way by a common law of motion. Professor Porter of Cincinnati has treated the problem in this manner of grouping, and has obtained similar results.

Several investigators, Schönfeld, L. Struve, Stumpe, Ristenpart and others have introduced into their discussions an assumption regarding a common motion among the stars. Additional terms are entered in Airy's equations, based upon the adopted hypothesis. If this hypothesis is true, discrepancies will disappear, and the new unknown quantity which expresses the supposed motion,

* *Astronomische Nachrichten*, No. 3000.

will evaluate in a consistent manner. Their results, however, have not justified the assumptions which have been made. It remains for the future to discover what law binds together the motions of the stars, if such common motion exists. Professor Kapteyn of Groningen maintains that there is an inherent defect in Airy's method, and that the inconsistences in declination of apex, as shown in Stumpe's values, are to be attributed to that defect. He has himself proposed a new mode of dealing with the problem.*

A recent determination of the apex, published by Professor Comstock of Washburn Observatory,† is of especial interest, because it is based upon faint stars of the tenth magnitude, none of which have previously been employed for this purpose. Further, Comstock determines distance by a new empirical formula, devised by Kapteyn, which makes parallax a function of both magnitude and proper motion. Kapteyn deduced this formula from all available data, and it has been found to correspond remarkably well with known mean values. The resulting apex-co-ordinates will be seen, by the table, to agree well with other determinations, although the number of stars involved was small.

Before passing on to the spectroscopic investigation of solar motion, I will briefly describe a method suggested by Bessel, and revived in recent years by Kobold. In 1818 Bessel criticised the procedure of Herschel and proposed the following graphic method, as better suited to the conditions of the problem.

Supposing proper motion to be wholly parallactic, the poles of all the great circles of proper motion would lie along one great circle, of which the solar apices are the poles. This great circle is called the parallactic equator. The data of observation give the positions of these poles. They will not lie on the parallactic equator, because errors of observation and peculiar proper motion cause deviations, but they will group themselves about it. Bessel's plan consisted in plotting these poles on a globe, and passing a great circle through them, in such a way as best to represent their general trend. If the parallactic equator is located, the apex is determined. Kobold has put this method into an analytical form, to which the principles of least-squares can be applied. In fact, the least-squares treatment is the analytical equivalent of passing a smooth curve through scattered points, whose scattering is due to accidental errors. Kobold's right as-

* *Astronomische Nachrichten* 3721.

† *Astronomical Journal* No. 558.

cension accords well with other determinations, but his declination lies much farther south.

The spectroscopic investigation of solar motion leads us into quite another field. Proper motion, as we have regarded it and as we still define it, has no part in this discussion. Proper motion is change in position on the celestial sphere. If a body is moving in the line sight connecting eye and body, or if the observer is moving in that line, there will be no change of position. Therefore proper motion is at right angles to the line of sight, and this component of motion is the only one revealed by the astronomy of position. But the spectroscope reveals the radial component and no other. In this remarkable way do the old and new astronomy fit together.

I cannot in this place enter into any exposition of the principles of astrophysics. I can only state that if a star is moving toward or from the observer, or the observer toward or from the star, a shift is caused in the lines of the star's spectrum. For approach the shift is toward the blue end, for recession toward the red. This shift can be measured with great accuracy in the photograph, by comparison with the lines of terrestrial gases photographed side by side with the stellar spectrum. The degree of refined measurement possible with the spectroscope transcends immensely that attainable in the astronomy of position. For the latter a mile must be a negligible quantity, because we expect errors of much larger size, but a mile a second with the spectroscope tells its undeniable story. Further, this radial motion reveals itself quite independent of distance. Is the luminous body ten miles away or is it millions of miles away, the shift of the line is the same for an equal velocity.

The bearing of this line displacement upon the motion of the solar system is at once apparent. The displacement immediately measured is, of course, due to motion of the solar system, plus that of the Earth around the Sun, plus the motion of the star. The effect of the second motion, that of the Earth round the Sun, is easily eliminated, since we can compute the velocity of the Earth in any given direction at any given time. We can, as we say, reduce to the Sun. There remain, therefore, as in the astronomical problem, the star's own motion and the Sun's motion, in this case along the radius connecting the two. Considering the Sun's motion only, it is plain that stars lying at the apices will have the largest shift of lines, those lying on the parallactic equator will show no shift, and those lying between will give displacements varying according to distance from apex.

Although the data of our problem thus spectroscopically considered are so different in character from the data of astronomy, the mathematical solution takes us back to the group of equation (5). The change in distance d*d* is the very datum given by the spectroscope. If the unit of time is one second, d*d* is the radial velocity per second of the star, plus the velocity of the Sun toward or from the star. The question of the star's own motions must be dealt with here as in the astronomical methods. They are regarded as accidental errors. The equation furnished by each star is, therefore,

$$dd = -\cos\alpha\cos\delta X - \sin\alpha\cos\delta Y - \sin\delta Z.$$

The least-squares treatment of the whole set of equations gives the most probable values of X, Y and Z. Thence, as before, A, D and *l* come from (1). Since, however, d*d* is expressed in miles per second, X, Y, Z and *l* will also be expressed in miles per second, i. e. as above stated, velocity is given at once by the solution without knowledge of distance. It will be noted that *d* does not enter in this third equation of (5).

The spectroscopic method already supplies our most trustworthy values of *l*. In time it will also afford excellent values of A and D. At present the number of stars available through their radial velocities is small. But several of our astrophysical observers are now engaged in a co-operative plan to bring into line, for this and other investigations, all the stars in the sky bright enough to record their spectra upon the photographic plate.

I append a table of values. I will include recent determinations of A, D and *l* by Newcomb.* He derives *l* from observed parallaxes of stars, combined with their proper motions, by the use of the equation, p. 229, of my last paper. He obtains more than one value, and I will give that one, which he regards as least effected by biassed selection of stars. His A and D are found by a discussion and combination of various determinations. The solar velocity is expressed in miles per second.

Investigator.	A.	D.	$\frac{l}{d}$	l	Method.
	°	°	″		
Herschel	245.9	40.4	0.75		
Argelander	259.8	32.5			Argelander
O. Struve	261.5	37.6	0.34		"
Galloway	260.0	34.4			"
Mädler	261.6	39.9			"

* *Astronomical Journal*, No. 457.

Investigator.	A.	D.	$\frac{l}{d}$	l	Method.
	°	°	″		
Airy	261.5	24.7	1.91		Airy
Dunkin	263.7	25.0	0.40		"
Bischof	285.7	48.5			Argelander
Bischof	290.8	43.5	2.60		Airy
L. Struve	273.3	27.3	0.34		"
Stumpe	283.0	41.2			" adopted value.
Boss	283.3	44.1	1.97		"
Porter	281.2	40.8			" adopted value.
Comstock	297	28			"
Kobold	266.5	— 3.5			Bessel
Newcomb	277.5	35		10.2m	
Vogel	206.1	45.9		11.6	Spectroscopic
Campbell	277.5	20		12.4	"

STEREOSCOPE APPLIED TO ASTRONOMICAL RESEARCHES.*

G. VAN BIESBROECK.

We have recently seen the stereoscope, an instrument old in principle, become, in skillful hands, an unexpected means of investigation. This modest apparatus, which seems rather to belong to the entertaining side of natural philosophy, suddenly appears as a new resource which promises to be fruitful in very varied applications. It is based on one of the simplest principles, whether we consider the old stereoscopes of Wheatstone (1838), and of those of Brewster (1850), or the more perfect apparatus which dates only two years back and which is designated under the name stereo-comparator.†

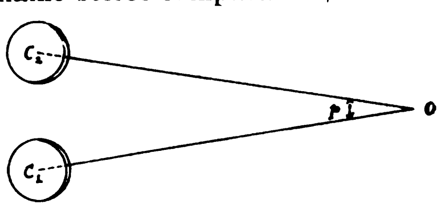


FIG. 5.

Let us recall how we see objects in nature. Let us suppose an observer whose eyes are normal, to be looking at any object whatever, as O, Fig. 5, at a distance which shall not be too great. Each eye being directed toward the point O, the two visual rays form an angle p, which is the parallax of the object. The observer must then turn the right eye C_1 a little to the left of its

* From Feb. No. 1904, Bulletin of the Astronomical Society of Belgium. Translated from the French by Miss I. Watson, Department of Modern Languages, Carleton College, Northfield, Minn.

† These notes are taken from a series of articles published by Dr. Pulfrich in the Zeitschrift für Instrumentenkunde 1901 Nos. 8, 9, 1902 Nos. 3, 5, 6, 8. Berlin J. Springer.

normal position, the left eye C_2, a little towards the right. It is the physiological effect accompanying the corresponding tension of the muscles of the eye which produces in us the idea of distance, or, what amounts to the same thing, the sensation of relief. If O draws nearer, we feel that we must make an increased effort to follow it with the two eyes; on the contrary, if it recedes the eyes tend to take again a parallel position, and we perceive without the help of any other means that the distance is increasing. Yet the perception is limited for the naked eye; experience has proved that for a distance greater than 400 to 500 meters, i. e. about 450 metres, the eye becomes incapable of feeling the sensation of relief. For such a distance the angle p is reduced to 0.5, the normal separation of the eyes being 65mm.

Then let us suppose that instead of looking at a real object two stereoscopic images i_1, i_2 are examined through two lenses, L_1, L_2 placed before the observer's eyes C_1, C_2 (Fig. 6); let us suppose at O_1 is represented any object whatever on the first image i_1. This same object is found again at O_2; for example, on i_2. If the two points O_1 O_2 are perfectly placed, the eye C_1 will see the object O_1 following the direction C_1 O_1, while the left eye will see the same object in the direction C_2 O_2; the two impressions on the retina unite in one producing the illusion of a single object O, which would be situated at the intersection of the two lines C_1 O_1 and C_2 O_2. If A is the distance of the eyes, A^1 that of the two corresponding points O_1 and O_2, the distance D at which the object O seems to be found in space, is obtained by:

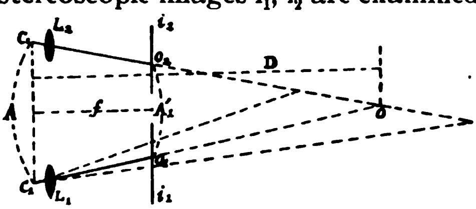


FIG. 6.

$$\frac{D-f}{D} = \frac{A^1}{A}, \text{ whence } D = \frac{Af}{A - A^1},$$

indicating by f the distance of the two images from the eyes of the observer. The lengths f and A are constant for the same apparatus and the same observer: let us note that if the images include several details for which the distance A^1 is the same, the different points will appear to be removed the same distance into space. If A^1 is greater, the corresponding point will appear in a plane more distant than the first. One can easily demonstrate this by arranging so as to vary the distance of A^1; for this purpose let us represent the two corresponding figures O_1 O_2 by two points, one of which O_2 is fixed and the other O_1 movable by the

aid of a micrometer screw. We seem to see but one point suspended freely in space; bringing O_1 nearer to O_2 it seems as though the point O traveled along the line O_2 L_2 and was approaching us; on the contrary removing O_1 further from O_2, the point O appears to us more and more distant on the same line.

It is seen at once that this very simple arrangement may serve to obtain the distance of any object. Let us project the image of the points, which we have placed in the focal plane of the lenses, on the object examined; let us move the movable point O_1 until the virtual point O_1 which can be made to change by the aid of the micrometer screw, seems to be at the same distance as the object whose distance we are trying to find. This being done, the apparatus gives A^1, and knowing the constants of A, the distance D is found from the relation given above. Such is the simple principle of the stereoscopic telemeter. A piece of apparatus constructed in this way would necessarily be of very limited usefulness. The distance between the eyes is, in fact, a very small base of operation for determining considerable distances. It was to meet this difficulty that Helmholtz invented his reflecting telemeter (1857), in which the course of the luminous rays is directed according to the following design (Fig. 7).

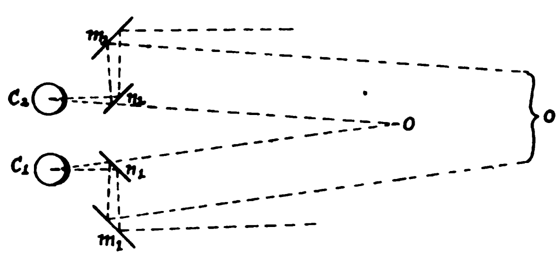


FIG. 7.

The luminous rays come from a distant object O after having undergone two reflections by two groups of parallel mirrors, which adjusts them to the distance the eyes are apart. To the eyes the object O removed to a great distance will seem to be at the point O^1, the intersection of the two straight lines C_1 n_1 C_2 n_2, along which the eye receives the luminous rays coming from O_1 and respectively parallel to the directions Om_1 and Om_2, going from the object to the mirrors m_1 and m_2. Everything takes place as if the observer's eyes were themselves spread apart to the distance of the mirrors m_1 m_2; in other words, the base of operation for perceiving the relief is multiplied by the ratio of the distance of the two mirrors to that of the eyes. Dr. C. Pulfrich of Jena has taken up this idea in his stereoscopic telemeter and made considerable improvement; instead of the simple mirrors of Helmholtz we find here two telescopes twice bent, whose eye-

pieces can be adjusted exactly to the distance of the eyes, and whose objectives are separated to a distance of one and a half meters, in the largest kind constructed by the firm of Zeiss. So that, if for simple vision the stereoscopic effect reaches to an estimated distance of 450 meters, the new apparatus will extend to about 10 kilometers; in order to make it the most practical possible, movable points are not used, but a series of fixed references,—they are placed at the focus of each of the objectives and, stereoptically combined two by two, they appear like a series of points, farther and farther removed and forming a scale of distance. The distance is read immediately by noting between what references any object seems to be. It is needless to insist upon the great advantage that one may gain from this apparatus especially in topography.

It is remarkable to be able to estimate distances of several kilometers with the aid of a base having a length of not more than one and a half meters, yet it is desirable to be able to determine still greater distances; for instance if it were desired to measure that of the shooting stars, or of taking measures of the aurora borealis, it is certain that the base ought to be 10 or 20 meters at least in order to make the same conditions as for a landscape. And if one wishes to apply the same means to determine the distances of celestial objects; Moon, planets, comets, even stars, the dimensions of the Earth itself would not be sufficient to furnish a proper base.

To avoid this difficulty Mr. Pulfrich has constructed an ingenious instrument which he calls the stereo-comparator. (Fig. 8).

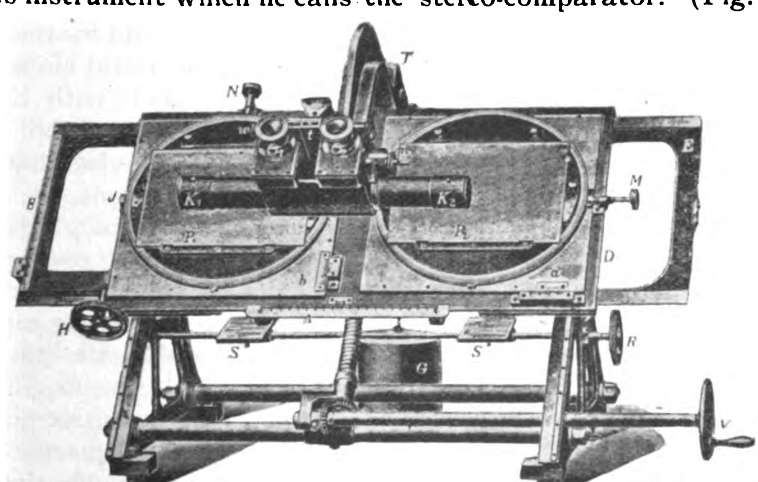


Fig. 8.

It serves the same purpose as the stereoscopic telemeter, but instead of making the measures on the object itself which is to be studied, operations are made on photographic images which are examined with the aid of a binocular microscope at a great distance from the objective. If one should unite in an ordinary stereoscope the photographs taken with the help of two instruments whose optical axes are parallel and are at the distance of the eyes, one would evidently experience the sensation of projection such as there is in reality. If the two objectives are separated farther, for instance up to one and a half meters, the combination of the two photographs will give rise to an increased relief just as in the telemeter. But nothing hinders us from increasing indefinitely, so to speak, the distance between the two positions from which are taken the views to be combined in the stereo-comparator. The photographic instruments are arranged with this purpose, as Fig. 9 indicates: in C the photographic chamber is supported bv a mounting similar to that of a theodolite. It turns about a horizontal axis, AA, to which is attached on the one side a graduated circle L_1, and on the other side a bent eye-piece OP; the axis AA can move in azimuth by rotation around a vertical axis V, a rotation whose amplitude is read by the aid of a horizontal circle L_2. A standard with three leveling screws and furnished with a level makes possible the setting of the instrument. In front of the eye-piece may be placed a Prandlt prism P, turning about the axis of the eye-piece and reflecting the luminous rays at a constant angle of 90° with the optical axis of the telescope. The observer placing his eye at the eye-piece O sights along the line PP′ perpendicular to the optical axis of the photographic system, an axis itself determined by cross lines traced on a glass plate arranged in front of the sensitive plate. The two instruments are oriented so that at the focus of each eye-piece is seen the image of the prism covering the objective of the other eye-piece. When this condition is fulfilled, and the in-

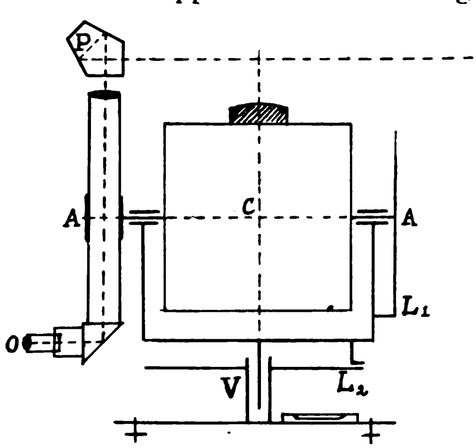


FIG. 9.

clinations of the lines of sight to the horizon are the same,—their inclinations being read by the graduations R_1 of the circle L_1—one is certain of obtaining two photographs on plates situated in the same plane, perpendicular to the base used. The operations to be done on the stereo-comparator are of remarkable simplicity. According to conditions, one will make use of a single instrument placed successively at the two posts of observation, or one will use two identical instruments operating simultaneously. The first case will present itself when there is a rise of ground for instance, or again in stellar photographs; but here the parallelism of the optical axes during the two photographs will be obtained by using a fixed star as a guide. On the other hand the two instruments will be used when one wishes to obtain stereoscopic views of clouds, lightning flashes, shooting stars, etc.

Let us now examine the stereo-comparator by the aid of which we shall study the plates obtained. Figure 10 represents the first style, such as was constructed by Dr. Pulfrich for plates 13 x 18 cm. The plates are arranged on an inclined frame work in the form of a disk, and they may be oriented in their plane or adjusted in two perpendicular directions by measurable amounts. A bent arm attached to the top of the framework supports the optical part in front of the plates; it will be a reflecting stereoscope when one wishes to judge of the plate as a whole; or a binocular microscope when one wishes to study the plates in detail and to take measurements on them. In the first case the course of the luminous rays is similar to that which takes place in the telemeter of Helmholtz. The arrangement of the binocular microscope is outlined in Fig. 10; O_1 and O_2 are the objectives, I_1 I_2 the eye-pieces of the two bent microscopes; R_1 R_2 represent the location of a system of lenses reflecting the images received from the plates P_1 P_2. In the plane of the images p_1 p_2 a movable mark is changed by a micrometric screw m, which comes into play in the measure of distances. The binocular apparatus is necessary to determine this; but it is evident that it also furnishes

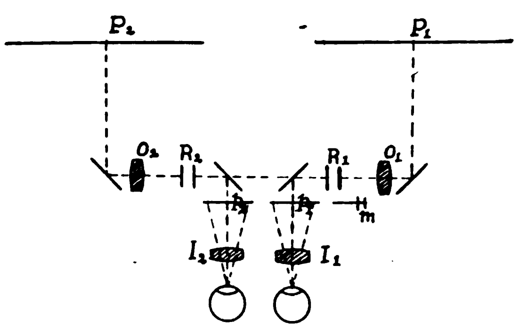


Fig. 10.

the two other co-ordinates, the height and the width of the objects; then a single microscope may be used just as in the comparators already employed for several years in measuring stellar photographs.

We now have at our disposition an apparatus which presents advantages over all the means hitherto at hand. In the first place, the stereoscope wins for itself a very natural satisfaction; look for instance, at such a view taken in the mountains at the extremities of a base of 45 meters. What striking relief! It is true, one does not realize in examining this picture the impression of grandeur that strikes the traveller going over the gigantic contorsions of the Alpine soil. By no means: one might rather imagine himself in the presence of a sculptured model, on a reduced scale, reproducing with wonderful delicacy all the details of the surface. Evidently it can be used to reproduce in relief on a small scale all the details of which stereoscopy has given evidence.

Then let us look at the photographs of the Moon; they are slides obtained by Messrs. Loewy and Puiseux and which have been combined in the stereo-comparator; they represent nearly the same phase of the Moon; but it is noticed that, in consequence of the well known phenomenon of libration, the satellite does not present to us exactly the same face. The whole appearance here is as if, the Moon remaining fixed, the observer had changed his position with regard to it, by an angle equal to the libration; at the distance which separates us from the Moon, this amounts to a displacement of about 100,000 kilometers in the case considered. Then bringing together in the stereoscope the two images obtained at the extremities of a base of this length, a very clear sensation of the rotundity of our satellite is obtained. Much more, Mr. Pulfrich has been able, by the aid of the movable point in the field of the microscope, to trace on the curved surface of the Moon a series of lines uniting points at th same distance from the observer and to obtain a system of curves on a level, analagous to those traced on the geographical maps and enabling us to follow in detail the structure of the lunar surface.

Let us examine in the same way the two photographs representing Saturn, including the mass of stars surrounding ξ Ophiuchi. These two views taken by Mr. Wolf at the Heidelberg Observatory June 9 and 10, 1899, when examined by the stereoscope give a legitimate surprise; the planet—with two of its satellites even—appears freely suspended in space very far in front of the background of the picture formed by the group of neighbor-

ing stars, which seem, because of the immense distance, infinitely removed in the same plane. Figure 11 enables one to understand the effect: O represents the Sun; T_1, T_2, S_1, S_2 respectively the positions of the Earth and of Saturn on the 9th and 10th of June 1899, a period near the time of opposition. The first day the planet is seen in the direction $T_1 S_1$; the second day it appears in the direction $T_2 S_2$. The combination of the two views in the stereoscope produces the same effect as though one were looking at the planet with the right eye at T_1, the left eye at T_2, that is to say, as though Saturn were at S.

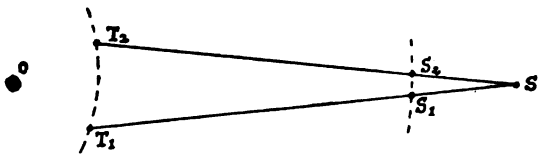


FIG. 11.

In the direct view with the naked eye the base of operation is about 65 milimeters; in the stereoscopic telemeter this distance is extended to one and one-half meters; then we have seen by what arrangement this distance may be increased to 10, 20, 100 meters and even more. Finally we find ourselves enabled to use a base of more than 2,500,000 kilometers, thanks to the revolution of the Earth around the Sun. It is not surprising that with the eyes spread apart to such a distance one can take account of the disposition of the stars in space. Let us note also that we see Saturn not at its real distance from the Earth, but at a point S farther away than S_1 or S_2, because of the movement of the planet while the Earth moves from T_1 to T_2. If Saturn had remained motionless in the interval the stereoscopic effect would have been still more obvious.

We can examine the comets in the same manner and assure ourselves that the tail is undoubtedly turned away from the Sun; more than that, we shall have a means of gaining exact information of its structure and of its dimensions. For, let us note in this connection, one can effect pointings on an object with a definite outline like the image of a star, with the same ease and the same precision as on those with blunt or poorly defined outlines, such as the foliage of a tree, the smoke coming from a chimney, the clouds of the atmosphere or the nebulæ of the sky. It is a fundamental property of the stereoscope; the importance of this peculiarity will be noted especially in the search for the height of the clouds for example, when the lack of points of reference necessary for exact setting is the principal cause of the uncertainty which this study admits of with the means used up to this time; it will be equally valuable in the study of the displacements or

modifications which the nebulæ undergo, a field in which our knowledge is still very incomplete.

On the other hand stereoscopy furnishes a very simple means of comparison of two plates of the same object. One could examine them by transparency by placing them one over another and find out whether certain details are not different in the two images. But this is an extremely laborious procedure and not very exact, especially when one is studying stellar photographs, for it will be necessary to pass constantly from one plate to the other to assure one's self whether a change thus indicated is real and does not result from a defect or from an alteration of the plate. Here, on the contrary, it suffices to give a glance into the stereo-comparator: at the slightest difference in the two objects, certain parts appear to detach themselves in front of the others or they announce themselves by a trembling, an instability in the image when they are of different brilliancy or are found only on one plate. This property is susceptible of innumerable applications: we can utilize it to study, for instance, the slow displacement of a glacier, to prepare and verify graduated scales, characters of printing, etc. We can also apply it to the examination of the spectrum of stars with reference to their radial velocity; the displacements of the rays by virtue of the Doppler-Fizeau principle will make them appear in planes different from the rays of the spectrum of comparison. The measures that can here be taken will be much more exact than by the actual means, since the lack of clearness of the rays or bands is no longer an obstacle to the precision sought for.

We have here also a new means of attaining the knowledge of the proper motion of the stars. Until now a limited number of stars could be examined from this point of view. They are in general brilliant stars easy to observe with the meridian instruments or lending themselves to micrometric measures by their relation to neighboring stars. But for the greater number of faint stars, for the nebulæ, nothing is known as yet. It would be necessary to have recourse to photography and to remeasure carefully, after a pretty long interval, the positions of these innumerable stars in order to assure one's self of an eventual displacement, a work which would require an immense amount of time. What have we to do here? It is enough to unite under the stereo-comparator the two plates representing the same region of the heavens; if certain stars have changed their place, they will appear to detach themselves from the mass of other stars which form a flat background, as in the stereoscopic views of Saturn.

This applies equally well to the small planets that can be found with the help of two photographs taken at a relatively short interval. These stars strike the eye at once on the inspection of the plate without its being necessary to search laboriously for them. It is, so to speak, impossible not to see them. It is thus that Mr. Wolf, well known for his numerous discoveries of little planets, had submitted to Mr. Pulfrich for inspection two plates on which he had recognized several asteroids after a minute comparison; Mr. Pulfrich, although entirely inexperienced in these researches, discovered at a glance, with the help of his new stereo-comparator, all the objects noticed by Mr. Wolf, and pointed out besides a new asteroid which had escaped the Heidelberg astronomer, who must nevertheless be considered as the man the most experienced and the most skillful in this matter.

Finally, the variable stars will not escape the observer either. They distinguish themselves by a sort of scintillation contrasting with the tranquil and steady light of the background. They strike the eye and even produce a sensation so disagreeable that one cannot mistake them. Quite recently Mr. Wolf published the result of the comparison of photographs of the large nebula of Orion. Thanks to the stereo-comparator he finds in it not less than twenty-four new variable stars, among which several are remarkable. Finally the defects of the plates, which it is also very important to recognize, become evident in the same way.

Without doubt, before being able to study by this means the proper motions of the stars, and, what is still more delicate, to determine thus the stellar parallaxes, the art of photography must be brought to greater perfection; there will be many difficulties to overcome, arising especially from the dispersion caused by the atmosphere, and from the difference in the coloring and composition of the light of the stars.

Still the different experiments where stereoscopy has been put in practice have appeared up to this time so convincing that one can hardly prophecy yet where the applications of the new method will end.

OBSERVATIONS WITH A SMALL TELESCOPE.

CLARENCE W. CARLISLE.

FOR POPULAR ASTRONOMY.

The question is often asked: "What can I see with a small telescope?" We all hear of the achievements of the great telescopes of the world, but little is said of the instruction and pleasure which can be obtained from the use of a small telescope. The writer has a small telescope, 1 9-66" clear aperture, which is provided with an inverting eye-piece of fifty diameters and an ordinary eye-piece of twenty-five diameters, and securely mounted on a firm tripod—a firm mounting being as essential as a good glass. For the benefit of the amateur who does not yet possess a telescope, and those who are unaware of the pleasure to be derived from its use, I will mention some of the most interesting objects to be seen with a small telescope.

The moon and planets are, of course, the most interesting to the beginner from the fact that they are nearer to us than the stars and, therefore, present greater detail. We will begin with Mercury, the nearest to the sun and by far the shyest of the planets. I have found that the best time for seeing Mercury in the evening is during the months of May and June, for then he is usually not only at greatest elongation, but appears farther north of the sun, and consequently remains in sight much longer than at other times. He then appears as a half moon, whitish in color, and on clear evenings is easily seen if one looks in the right place; if this position is known, a star map will aid in locating him. When one is fortunate enough to observe him for a week or more at a time, a change in phase is noticeable.

When Venus at her greatest brilliancy hangs in the evening sky, she appears as a beautiful crescent. The one great drawback in obtaining good views of Venus is her great brilliancy, but if one will begin observations at sunset, or a little before, very good views may be obtained. When at greatest distance she is so small and far away that nothing is made out; but from greatest elongation to inferior conjunction her change from half moon to a slender crescent, accompanied by an apparent increase in diameter, is one that will be closely followed by the true lover of the stars.

Mars, the best advertised of all the heavenly bodies, is, perhaps, the most disappointing to the small telescopist. He presents a small, ruddy disc, which is seen to increase and decrease in size as he approaches and then recedes from the earth. I presume that at the most favorable opposition one or two of the larger markings could be seen

and, possibly a slight change in phase. Of course his moons and canals can never be seen with a small telescope.

The first glimpse of Jupiter through a telescope is a sight long to be remembered, and never fails to bring an exclamation of wonder. The yellow disc of Jupiter looks somewhat like our moon seen with the naked eye (in fact, with a power of 50 diameters, the image is really larger than our moon), and his ever moving satellites appear like so many little golden balls. The moons of Jupiter dart back and forth, passing in front and then behind his great globe, in nearly a line with the equator. If one has an ephermeris he may spend many pleasant hours watching the eclipses of these tiny moons. Even if one has not an ephemeris he may often see an eclipse, or at least the emersion of the moons from the shadow, for a chance of observation will often show Jupiter with three or even two moons, and on rare occasions he is seen to have but a single satellite. The transits of the moons and shadows across the planet's disc cannot be seen with so small a telescope. Jupiter's belts, on either side of the equator, are clearly seen, and at present the southern belt appears nearly twice as wide as the northern belt. These belts cannot be traced to the limb of the planet, but appear to terminate a very short distance from it; this is due to the fact that we are looking at a globe and not a flat surface. Jupiter appears somewhat larger at oppostion than at greatest distance and the difference in the length of the equatorial and polar diameters is apparent to the keen observer.

Saturn makes a very beautiful picture. His little globe is surrounded by a flat ring and the space between the ball and the ring is plainly seen. With our telescope the ring cannot be separated, and at present none of the moons can be seen; altho, as Saturn gets higher up at each succeeding opposition, I presume that his largest moon, Titan, can be seen. A two inch glass would probably show it at the present time. It will be interesting to watch the gradual closing up and final disappearance of the ring as it is presented edgewise to us.

Uranus is practically invisible to the naked eye, and far from an imposing object in the telescope. He can be picked up from time to time as he passes near a star or another planet. Knowing the approximate position of Uranus, the writer has found that by making a rough map of the stars in that vicinity, and then about two weeks later making another map, a comparison of the two will show Uranus for altho his motion is slow it is sufficient to give him away. Of course, Uranus is so far away that his moons are not seen, and he appears like a small star. Neptune, invisible to the naked eye and but barely visible in a small telescope, moves so slowly in his orbit that it is very

difficult to pick him up among the great multitude of small stars.

The moon is, by far, the most interesting object for our small telescope. Each day reveals the moon in a new light, and one never tires of looking at it. When at the quarters the moon is most interesting, for then the shadows are longest, and the great mountains stand out in bold relief. I will not attempt to describe the wonders of the moon for they are too numerous as anyone who has looked at it, even with an opera-glass, is well aware. Copernicus, Tycho with its rills, the Apennines and the Alps with its deep ravine, the lunar railway, the great seas, and all the other grand objects on the moon can easily be identical with the aid of a small chart of the moon.

We will now turn our telescope on the stars. The Pleiades and Hyades in Taurus will be the first to draw our attention, and when seen with a low power they present a very beautiful appearance, very many stars being seen which the naked eye does not reveal. The double cluster in Perseus contains a great number of small stars, ranging from the sixth magnitude down to the fourteenth, but of course with our telescope we can see only the brightest. The globular cluster in Hercules can be found with a little patience, but the stars are so thick that they cannot be separated and it appears like a nebula. The bee-hive cluster in Cancer should also be carefully examined.

Among nebulae the great nebula in Orion stands out pre-eminent. To get the best effect this should be allowed to drift slowly into the field of view, using a low power eye-piece.

This nebula is very irregular in shape and contains several small stars. Near the center three very faint stars and one brighter one are seen, composing the trapezium. The elliptical nebula in Andromeda, and the only one visible to the naked eye, is worth a very careful examination.

On turning to the double stars we shall find that our telescope will separate a great number, ranging from the widest doubles, such as Epsilon Lyrae, and Mizar in the handle of the big dipper, down to Gamma Arietis and Gamma Andromedae, whose distances are 8.5 and 10 seconds respectively. Beta Lyrae has four companions, two which we may see; one is conspicuous, but the other requires some patience. One of the most interesting doubles is 61 Cygni, the first star whose parallax was measured, and the second nearest star to us. Its components are of equal magnitude and separated about 21 seconds. Beta Cygni is, perhaps the prettiest double that our telescope will show. Its components present a very striking contrast in color, one being bright yellow and the other blue. One of the most difficult doubles is Delta Bootis; a dark night, good seeing, and consider-

able patience are required to catch the faint companion which is of 8 1-2 magnitude and separated 110 seconds. There are many other double stars scattered throughout the constellations which our telescope will show, Bootes, Orion, Canes Venatici, and Scorpio being particularly rich.

During the present solar activity frequent examinations of the sun will be very profitable. For this purpose the telescope should be provided with a dark eye-piece, or sunshade as it is sometimes called. During the last six months one or more sun-spots have been visible almost daily; one day the writer counted fifteen, large and small. The faculae are not seen very plainly, but the large spots are seen to be jet black in the center surrounded by a grayish matter. These large spots are often seen to break up into several smaller ones, and they assume various shapes. Last fall the writer noticed a singular group of small spots which appeared to be protuberances rather than depressions, resembling some of the smaller mountains of the moon. To be instructive the sun should be examined daily so that the changes in the shape of the spots can be closely followed.

Besides the regular phenomena, there are occasional displays, such as comets, occultations of stars by the moon, eclipses of the moon and if one is fortunate enough to live in the right place, an eclipse of the sun.

Comets have always appealed very strongly to the writer, for one never knows what they may develop, and even tho they remain inconspicuous their rapid flight among the stars will prove of interest. Perrine's comet, which appeared in the summer of 1902, was insignificant. Borelli's comet of last summer was a great improvement over Perrine's and at brightest shone as a star of the fourth magnitude; the head of the comet was quite clearly defined, and the tail could be traced for several degrees. However, opera-glasses will be found more effective in examining comets as they admit more light.

Occultations of bright stars by the moon ought to be of great interest to the amateur as they afford opportunities of proving to his own satisfaction that the moon has a very thin atmosphere if any at all. Unfortunately for the writer the occultations of the last two years have occurred on cloudy nights and, therefore, no observations could be made.

Truly, when one contemplates the wonders and glories of the universe, he is forced to say in the language of the scriptures: "What is man that God is mindful of him."

VARIABLE STARS IN THE NEBULA OF ORION.

EDWARD C. PICKERING.

The Great Nebula of Orion has been the subject of careful study by astronomers for many years. Volume V of the Annals of the Harvard Observatory contains an elaborate discussion of this nebula, by Professor Bond, including a comparison of the material previously collected. Many stars in it have been announced as variable, but strangely enough the changes in only one of them, T Orionis, have been generally admitted. In 1901, and again in 1903, Professor Wolf of Heidelberg compared several of his photographs by means of stereo-comparators and announced a number of variables in this part of the sky. They do not appear to have been confirmed by other observers, and final designations have not yet been assigned to them. The faintness of many of these stars even at maximum renders it probable that comparatively few photographs exist on which they can be followed. A grant made by the Carnegie Institution for 1903, permitted a large amount of work of this kind to be undertaken here, and furnished a corps of eight observers for the study of the Harvard photographs. The failure to continue this grant for 1904 rendered it necessary to disband this corps, and since December, 1903, similar work has been carried on, at the expense of the observatory, by only one observer, Miss Henrietta S. Leavitt. A number of photographs of the nebula of Orion, having long exposures, are contained in the Harvard collection, and a careful examination of them has been made by Miss Leavitt. Besides confirming sixteen of Wolf's variables, she has found many new ones, which renders it probable that nebulæ as well as clusters may furnish fruitful fields for the discovery of such objects. Three plates taken with the 13-inch Boyden telescope were examined, the first made on September 15, 1893, exposure 180^m, the second on September 17 and 18, 1893, exposure 480^m, and the third on December 5, 1893, exposure 151^m. Plates taken with the 24-inch Bruce telescope, on January 8, 1894, exposure 60^m, January 25, 1894, exposure 60^m, January 27, 1895, exposure 180^m, October 6, 1896, exposure 180^m, November 9, 1896, exposure 123^m, November 10, 1896, exposure 265^m, December 17, 1898, exposure 60^m, December 3, 1901, exposure 60^m, and December 4, 1901, exposure 420^m, were also used. For stars which, on plates having long exposures, are deeply involved in nebulosity,

an examination was also made of plates taken with the 13-inch Boyden telescope on September 12, 1893, exposure 10^m, and on March 13, 1896, exposure 10^m, and of plates taken with the 24-inch Bruce telescope on November 30, 1893, exposure 61^m, December 27, 1893, exposure 60^m, January 1, 1894, exposure 11^m, January 1, 1894, exposure 60^m, October 29, 1897, exposure 10^m, and December 8, 1898, exposure 10^m. Some excellent photographs taken with the 8-inch Bache telescope in 1888 (Annals XVIII, 114) can be used only for the brighter variables. So far as possible, the map and catalogue of Bond (Annals V) were used to locate these stars, and their positions were derived by adding the co-ordinates given by Bond to those of θ^1 Orionis, whose position for 1900 is assumed to be R. A. = $5^h\ 30^m\ 21^s.3$, Decl. = $-5°\ 27'.3$. Estimates were made of the positions of stars not in this catalogue, and are given to seconds of time in right ascension, and to tenths of a minute of arc in declination.

A provisional scale of magnitudes was used which is fairly comparable with that of Wolf. On this scale, the faintest stars seen on Plate 26 of Roberts' Photographs of Stars, Star Clusters and Nebulæ, have the magnitude 14.8. The original negative was taken with his 20-inch reflector on January 15, 1896, and had an exposure of 90 minutes. The faintest stars shown in Plate XXIII of Volume VIII of the Decennial Publications of the University of Chicago have the magnitude 15.5. The original negative was taken with the 24-inch reflector on October 19, 1901, and had an exposure of 60 minutes.

A list of the stars certainly variable is given in Table I. Those found by Wolf have been confirmed by Miss Leavitt. Those found by Miss Leavitt have been examined by Mrs. Fleming, on several plates, and the variability in each case confirmed. Although the changes in some of these stars are small, they seem to be real since, owing to their faintness, good comparison stars can be found near them. A number for reference, the provisional designation given to Wolf's stars in the *Astron. Nach.* CLXII, 161, the number in the catalogue of Bond, the right ascension for 1900, and the declination for 1900, are given in the first five columns. The brightest and faintest magnitudes on the Harvard and Heidelberg photographs are given in the next four columns.

Table I.

Stars Certainly Variable.

No.	Designation.	Bond No.	R. A. 1900.	Decl. 1900.	Harvard. Br.	Harvard. Ft.	Heidelberg. Br.	Heidelberg. Ft.
			h m s	° ′				
1	...	...	5 27 53	−5 44.0	14.1	< 15.5	...	...
2	...	...	28 27	5 26.1	14.5	< 15.1	...	...
3	36.1903	...	28 37	5 16.1	14 4	14.9	13 8	15.0
4	...	...	28 37	4 47.6	14.0	15 0	...	...
5	...	173	28 37.0	4 48.2	13.9	14.6	...	...
6	...	...	28 40	5 5.7	13.3	14.6	...	...
7	...	...	28 47	6 22.8	12.5	< 15.5	...	...
8	...	...	28 54	6 44.3	13.2	15.5	...	...
9	...	...	28 59	5 45.8	13.2	14.1	...	...
10	37.1903	...	29 0	4 52.0	13.8	15.2	13.0	15.2
11	...	...	29 5	6 40.3	13.7	< 15.5	...	...
12	...	276	29 8.7	5 41.1	12.9	14.0	...	...
13	...	288	29 12.2	5 17.8	12.9	14.2	...	...
14	...	...	29 15	4 54.1	14.5	15.2	...	...
15	...	...	29 21	5 8.6	14.3	< 15.0	..	...
16	38.1903	...	29 24	6 40.0	11.4	14.1	13.0	15.0
17	...	...	29 29	5 35.0	13.5	14.8	...	...
18	...	...	29 31	4 49.5	14.9	15.5	...	...
19	...	417	29 42.8	6 9.6	13.4	14.5	...	...
20	...	419	29 43.0	5 39.0	14.1	14.6	...	...
21	...	435	29 46.0	5 26.8	12.1	12.7	...	...
22	...	...	29 47	5 50.1	14.2	15.5	...	...
23	...	...	29 49	5 14.8	14.2	15.5	...	...
24	...	481	29 54.8	6 2.0	11.8	12.8	...	...
25	39.1903	484	29 55.1	4 44.2	14.0	14.6	12.5	14.0
26	40.1903	509	30 1.6	5 50.6	13.2	13.9	12.5	14.0
27	...	511	30 2.1	5 45.7	13.4	14.0	...	...
28	...	...	30 2.5	6 27.9	13.1	14.0	...	...
29	...	520	30 4.3	5 58.6	14.1	14.9	...	...
30	...	...	30 5	4 54.8	12.7	13.1	...	...
31	...	...	30 12	5 40.3	12.9	14.7	...	...
32	...	561	30 12.2	4 31 7	12.2	14.6	...	...
33	...	...	30 13	5 41.1	14.1	15.0	...	...
34	41.1903	582	30 16.3	5 50.5	12.1	13.0	12.0	14.5
35	41.1903	596	30 18.2	4 49.7	13.0	13.7	12.7	< 14
36	...	606	30 19.5	5 47.2	12.7	13.7	...	...
37	...	620	30 20.7	5 43.2	12.7	13.1	...	...
38	...	...	30 21	5 56.1	13.8	14.6	...	...
39	...	...	30 24	4 57.8	14.2	14.9	...	...
40	...	668	30 25.5	4 46.2	12.4	13.0	...	...
41	43.1903	680	30 26.8	5 38.6	12.9	14.0	12.3	< 14
42	...	695	30 30.1	5 13.7	11.1	12.5	...	...
43	...	703	30 31.0	5 15.9	11.8	13.2	...	...
44	...	709	30 31.5	5 29.6	10.7	11.3	...	...
45	...	...	30 34	4 59.1	13.2	14.3	...	...
46	83.1901	756	30 40.0	5 5.1	11.6	14.2	11.8	13.2
47	50.1903	758	30 40.1	6 49.2	13.4	14.6	12.5	< 14
48	...	759	30 40.3	5 25.5	13.0	13.6	...	...
49	...	784	30 47.2	5 32.1	10.3	11.0	...	...
50	...	788	20 47.3	5 9.7	14.0	< 15.2	...	...
51	...	...	30 52	5 5.1	14.4	15.0	...	...
52	...	817	30 54.0	5 53 5	14.1	14.8	...	...
53	...	822	30 55.6	5 32.4	...	...	...	...
54	44.1903	...	30 57	4 51.1	13.3	< 15.0	12.8	< 15
55	...	838	30 58.1	5 8.0	12.3	13.3	...	...
56	...	...	31 0	6 25.5	14.1	14.7	...	...
57	45.1903	...	31 1	6 54.8	14.5	15.4	12.5	15.0
58	...	...	31 9	−4 45.5	14.0	14.8	...	...

TABLE I.—CONTINUED.

STARS CERTAINLY VARIABLE.

No.	Designation.	Bond No.	R. A. 1900. h m s	Decl. 1900. ° ′	Harvard. Br.	Ft.	Heidelberg. Br.	Ft.
59	46.1903	877	31 9.2	−6 46.5	13.0	14.9	12.6	< 14
60	...	885	31 13.8	6 18.2	12.8	13.9	...	...
61	...	...	31 16	6 52.0	14.4	< 15.4	...	...
62	...	...	31 18	6 33.3	13.7	< 15.0	...	...
63	85.1901	908	31 21.4	5 15.4	11.5	12.1	11.8	< 14
64	...	...	31 28	6 21 5	13.0	14.5	...	...
65	...	951	31 42.7	5 29.9	13.5	14.6	...	...
66	...	...	31 46	6 23.1	12.1	13.3	...	...
67	...	1009	32 8.8	6 37.1	11.5	< 14.8	...	...
68	...	...	33 3	7 1.2	13.7	14.4	...	...
69	86.1901	...	34 46.1	3 28.6	13.5	14.4	11.7	13.0
70	...	...	35 13	6 18.9	12.2	13.2	...	...
71	49.1903	...	36 36.0	−4 11.3	10.5	< 14.8	9.8	< 15

REMARKS.

3. Although the observed range is small, the variation is very clearly marked.

4, 5. The variation of these adjacent stars is marked.

6. Period apparently short.

12. Period apparently short.

13. Period apparently short.

18. This star, although faint, gives distinct images on the plates, and the variation is well defined.

20. The variation of this star, though small, is well shown by a comparison with three neighboring stars of about magnitude 14.5.

28. Bond 528 and Bond 537, the stars nearest this position, are wrongly charted on Bond's map. The position has, therefore, been determined independently.

30. The variation is obvious when different photographs are compared, but the strong nebulosity in the region of this star makes measurements of the magnitudes difficult.

37. The variation is small but readily observed, as the variable is sometimes brighter and sometimes fainter than Bond 605 which precedes it 1ˢ.2, and is in the same declination.

44. This star was suspected of variability by Holden.

47. Wolf announced this star as probably variable.

49. This star was suspected of variability by Schmidt.

51. Although this is a faint variable it is easily observed. A star of about the fifteenth magnitude follows and is slightly south of it.

53. T. Orionis. This star was not measured, but the variation is obvious, on the plates examined.

63. No marked variation was found in this star, which was observed with some difficulty.

64. This star is on Bond's chart, but not in the catalogue.

66. This star is on Bond's chart, but not in the catalogue.

68. This star precedes the position given by Wolf of 47,1903, 35ˢ and is north of it 18′.

70. This star precedes the position given by Wolf of 53,1903, 26ˢ, and is north of it 10′.

A list of stars suspected of variability is given in Table II, in the same form as Table I omitting the last four columns. All of Wolf's stars may prove to be variable, but some are included in Table II since they have not yet been confirmed here.

TABLE II.

SUSPECTED VARIABLES.

No.	Designation.	Bond No.	R. A. 1900. h	m	s	Decl. 1900. °	′
1	80.1901	...	5	24	47.0	−8	5.2
2	32.1903	...		26	59.2	4	31.4
3	33.1903	...		27	13.6	5	7.1
4	34.1903	...		27	16.6	7	32.8
5	35.1903	...		27	54.0	7	38.8
6	......	216		28	50.5	5	35.3
7	81.1901	...		28	54.0	4	42.8
8	......	...		29	15	5	36.3
9	......	361		29	29.1	5	1.1
10	......	492		29	56.8	4	7.5
11	......	...		30	0	6	33.5
12	......	524		30	5.2	5	27.0
13	......	527		30	5.6	5	48.5
14	......	558		30	10.7	5	29.3
15	......	...		30	14	5	35.5
16	......	...		30	17	5	34.5
17	......	...		30	25	5	35.3
18	82.1901	...		30	36.8	6	7.1
19	......	...		30	37	4	52.8
20	......	801		30	51.0	5	32.0
21	......	833		30	57.3	5	55.6
22	......	...		30	59	5	30.3
23	84.1901	...		31	0.4	5	0.8
24	......	...		31	5	6	1.3
25	......	...		31	37	5	20.8
26	51.1903	...		32	18.4	3	35.2
27	......	...		33	3	4	16.8
28	47.1903	...		33	38.4	7	19.2
29	52.1903	...		34	31.9	4	57.4
30	87.1901	...		35	10.1	5	24.4
31	53.1903	...		35	39.4	6	29.0
32	48.1903	...		35	57.8	8	8.5
33	54.1903	...		35	57.9	8	7.7
34	88.1901	...		42	27.9	6	14.8
35	89.1901	...		43	16.1	−5	43.6

REMARKS.

1. The region is on the extreme edge of the plates examined. No variation was detected in any star near the position announced.

2. No star near this position was found to vary with certainty. A fourteenth magnitude star was suspected of being unduly faint on January 8, 1894, and on January 27, 1895.

3. No variation could be found in any star near this position. Probably the variable remains faint during the greater part of the time, as it was seen bright on only one of the Heidelberg plates.

4. A star of about the magnitude 14.5 in this position appears to fluctuate slightly in brightness, but no conclusive evidence of variation has been found.

5. No variation was found in any star near this position.

7. Assumed to be Bond 223. On the plates examined the star is always of about the magnitude 13.5. No star near this position has been found to show variation.

14. This star is in a strongly nebulous region and the variation is possibly only apparent.

18. The star nearest the position is Bond 745, which does not show variation on the plates examined. On each of them it is of about the magnitude 13.5.

20. Bond considered this star to be variable. There appears to be some fluctuation in light, but on the plates examined, the evidence of variability is not conclusive.

23. Bond 844 is in the position given. On all the plates examined, the light remains at about the magnitude 13.7.

26. No variation was found in any star near the position given.

28. A star near this position appeared to be nearly half a magnitude fainter than usual on December 17, 1898. The images of stars in the vicinity are poor, however, and the evidence of variation does not appear to be conclusive. See remark on number 68 in Table I.

29. The star nearest the position given shows some evidence of variation. On the best plates, the brightness appears to be constant. On January 8, 1894 and January 27, 1895, the star appears nearly half a magnitude fainter than usual, but the images are poor in each case.

30. Of the two stars near this position, the southern always appears about two-tenths of a magnitude the brighter, except on the plates taken November 9, 1896, and December 3, 1901. On these plates the two stars appear equal.

31. No star near the position given shows variation on the plates examined. See remark on No. 70 in Table I.

32. The region is covered by only three of the plates examined, and on them the star is too near the edge for accurate observation. The northern of two faint stars near this position was suspected of being half a magnitude brighter on November 10, 1896 than on November 9, 1896. The two stars are doubtless Wolf's 48, 1903 and 54, 1903.

33. See remark on number 32.

34. The region is on the edge of the plates examined. No star could be found showing the progressive diminution of light announced by Wolf.

35. The region is on the extreme edge of the plates examined. No star near the position was found to show variation.

The region covered in this examination was that of Bond's map, which extends between the limits preceding and following θ^1 Orionis by $2^m\ 42^s$, and from 87′ north of this star to 91′.5 south of it. The corresponding limits for 1900 are R. A., $5^h\ 27^m.7$ to $5^h\ 33^m.1$, Decl. — 4° 0′ to 6° 59′. The area of this region is 14,458 square minutes of arc, and the number of stars examined about 3,000. A small region near the announced position of each of Wolf's variables, situated beyond the limits of the map, was also examined.

The distribution of the variables contained in Table I emphasizes their close connection with the nebula. They are found principally in a narrow region on each side of a line extending southward from *c* Orionis through θ and ι, and beyond. North

of declination — 4° 44′ only one variable was found out of about 900 stars examined. Within the limits of the remainder of Bond's map, out of 550 stars examined, only one variable has been found preceding R. A. $5^h\ 28^m.4$, and out of 450 stars examined, only one variable has been found following R. A. $5^h\ 31^m.8$. The areas of these three regions are 3524, 1417, and 2632 square minutes of arc, respectively. In the remaining region, covering 6885 square minutes, out of about 1100 stars examined, 65 have been found to be certainly variable, and 20 more are probably variable. A suspicion is also attached to several other stars not here announced.

It is not improbable that other variables may be discovered when more photographs become available for comparison, as many of those found appear to be of the same class as the variables in globular clusters, which remain at their minimum magnitude during a large part of the time. Those of Wolf's variables which were not confirmed upon the Harvard plates may belong to this class.—*Harvard College Observatory*, *Circular No. 78.*

March 23, 1904.

SEEN AND LEARNED ABROAD. II.

T. D. SIMONTON.

FOR POPULAR ASTRONOMY.

Let not our title be understood in disparagement of what we have at home. For our age, no land can present the student of science greater facilities for his studies, nor inducement thereto. At home or abroad, it is the intent and awakened mind that will win the prize of knowledge, equally valuable wherever acquired. But that a country such as Europe, that has seen almost all the civilized centuries, should have gathered more for the eye to see and the mind to contemplate, and have developed a line of men of science it is a great privilege and a great stimulus merely to be in the presence of, is surely nothing to be wondered at; rather it is to be gratefully prized as a fact and an opportunity for those coming from the newer world. And it is in this sense and from this point of view I now write of the advantages of an experience abroad, while still giving full weight to our opportunities at home.

It was the year of the Queen's Jubilee, when from the roof of a down-town theatre we saw probably the greatest crowd London has ever known, brought together to view the greatest concourse

of royalty in modern times—from Europe, Asia and Africa—royalty and aristocracy enough to do us for a life time. But how was it a few months later when we had a timely rest of ten days in the city of Manchester, to see and take part in another gathering, the meeting of the British Association for the Advancement of Sciences, the largest concourse of men of science Europe had probably ever seen up to that time? Counting both active and associate members they numbered nearly 4,000. With proper credentials,* on payment of 1 £ visitors like ourselves were admitted not only to all the sessions and sections of the meeting, but were welcome to the excursions and the public social features arranged for the entertainment of the delegates. Of the latter I shall only mention the Mayor of Manchester's reception of the delegates in the City Hall, where, in the crush of numbers, the toilets of the ladies, and the rather boorish attack upon the tables of refreshment on the part of some of the men, we saw what was sufficient to make us feel that we in America and they must be near of kin indeed, since everything was so blameably natural.

But now, in favorable contrast to the heterogeneous royalty of the Jubilee, here were the leading great men in science of Europe (with a number from America), in daily conference, following the more formal opening addresses of the general meeting and of the subdivisions or sections as they are called. Men I had often read about and revered for their attainments, such as Sir William Thomson (now Lord Kelvin), Sir Frederick Bramwell, Professor Playfair, Lord Rayleigh, Sir Henry Roscoe, Professor Newton, Professor Pritchard, Sir Charles Warren, Professor Boyd Dawkins, and many others, were now seen in the flesh, and had become living realities. In the lesser meetings of the Sections particularly, and day after day, a stranger even would become familiar with the pose and lineaments of these men; and perhaps I may be pardoned in transcribing from my journal the terms in which I tried to make indelible (there at least) the impression of them at that date. "Sir Wm. Thomson is an eager, ruddy faced man of over 60 years; has a keen eye, and an intent, nervous manner; seems to be alive to all that is going on, and to enjoy it. Lord Rayleigh is a large, sandy-haired, good-natured looking man, whom I shall remember from his wearing the long sparse

* It is but due Professor Payne I should say that a note from him was all I carried as an introduction to scientific circles abroad; and that even was shown very seldom. Once introduced, I seemed to have easy entrance everywhere.

locks of his hair over the top of his head, and his keeping (lost in thought) his hands in his pants' pockets! Sir Henry Roscoe is ruddy-faced and portly. They say he is of late something of a politician, after quite a career as a chemist."

And this latter name brings me to the Inaugural Address of the great meeting, for it was by Sir Henry E. Roscoe, the President of the Association, it was delivered. Besides the members, the elite of the city were evidently on hand; for it is no slight honor to entertain the Association. The subject of the lecture was "A Review of the History of Chemistry during Victoria's Reign." His opening sentence was, "Manchester, distinguished as the birthplace of two of the greatest discoverers of modern science, heartily welcomes today for the third time the members and the friends of the British Association for the Advancement of Science." And by the time he had given his masterly exhibit of the place Dalton gained as the discoverer of the laws of chemical combination, and as the framer of the atomic theory (on which modern chemistry may be said to be based), and Joule, none the less, by his experimental determination of the mechanical equivalent of heat, leading on to the great doctrine of the conservation of energy—by the time this was so successfully accomplished, one felt as though in a sacred vicinity and that it was a privilege to tread on the streets and pavements marked by the footsteps of these later apostles of science.

Several popular lectures were given during the eight days of the meeting, one by Professor H. B. Dixon, on the "Rate of Explosions" (of gases). It was concluded by the Professor's firing a tube containing explosive gases, running clear round the room and coming back to him, in plain sight, with a length of some three hundred feet. Deftly adjusted registering apparatus showed that only the 1/25 of a second elapsed from the firing at his desk at one side till the return impulse at the other side of the desk caused a little token to drop, indicating the time. Both the lecture and the admirably conclusive experiment were commended by Sir William Thomson in a few words at the close.

But the main business of the Meeting was to be seen in the Sections, of which there were six or eight, designated by the letters of the alphabet, A. B. C. etc. Section A., Mathematics and Astronomy, was opened by an address by Sir Robert S. Ball, Astronomer Royal of Ireland, and President of the Section. Following him was a paper by Sir William Thomson on Vortex Motion. In it he said we have in the jelly-like ether a means for the propagation of the waves of light, and that it represents

other more solid substances such as glass and diamond. Professor Pritchard (a D. D. also) Savilian Professor of Astronomy at Oxford, spoke on Celestial Photography. Gave his method of stopping off bright stars till the fainter ones had time to imprint themselves on the plate, and then giving the former just time enough for themselves. He claimed that by this method he could secure such perfect definition that he could get parallax to 1/10 of a second. He was criticised, but maintained his ground. I should take him to be 80 years of age (he died in 1893); he is very fleshy and bulky and short of breath. Mu Cassiopeæ (I now recall) was the star so closely determined as to parallax.

"Professor Pickering's paper on Stellar Spectrum Photography was not read, as the illustrative prints had not arrived. (I have seen the latter since here in London. They are exquisite productions). Professor C. A. Young was also present and seemed much interested. On another day he gave a report of the American Total Eclipse Expedition to Russia (station about 150 miles northwest of Moscow) from which he was returning. They had had fine weather right along, but when the final moment arrived the sky was hopelessly cloudy, to their inexpressible disappointment. The diminution of light was very apparent as the eclipse came on, but at the darkest the bricks could be separately distinguished on a house several hundred feet distant. A story was current among the peasants that Antichrist had come from America, and that now the end of the world might be apprehended! The great desire of the Professor was to have confirmed (if such be the fact) a conclusion of his drawn from a previous eclipse, that the reversing layer is found in the gases next to, if not in part in those within the photosphere. The observation was to be made just at the beginning or the end of totality, when those gases would be exposed near to, but not superposed upon, the photosphere, and were expected to flash out the bright-line spectrum. Later eclipses have satisfactorily shown this to be the case; for a moment or two hundreds of bright lines appear.

When I name Professor Rowland as the third distinguished American I heard before the Association (not to mention many scientists from the continent), the representative character of the Meeting from the standpoint of science may be understood. The Professor's paper was on Wave-lengths of the Spectrum. He was afterwards criticised for not using Angström's map, but was supported in his position by Professor Young, on the ground that Angström is not definite enough and refined enough for modern work. Rowland's manner before the Section seemed rather

feeble, but we shall see his matter was positive enough to stir it up. He gave in his report a description of his map of the spectrum. He had worked for several years with concave gratings—first with one of 12 ft. focus—then with one of 21 ft. Results he should show the Section in his photographs; that Angström is not correct.

Having made his negatives, the next thing was to place the scale upon them. He first tried Angström's numbers, but they would not match. He had therefore to determine the relative wave-lengths, and this he did by using overlapping spectra and micrometer measurements. As the spectrum was normal all that was necessary was to get the scale to agree at two points and then it would agree at all. * * * He could not fit a scale to his map until he had made a new determination.

Captain Abney thought it a serious thing to change the standard of wave-lengths and that a committee of the Association should be appointed to confer with an American committee. Rowland replied that Angström's numbers do not agree among themselves. His position seemed to be reflected in a report of M. L. Bell of Baltimore (a student of his?) on Recent Determinations of Absolute Wave-lengths, which closes as follows: "We can from the close agreement of Kurlbaum, Pierce (corrected) and the writer feel sure that the wave-length of D is very near 5896.00, and consequently that all wave-lengths based on Angström's values are incorrect by at least one part in 8.000. But this would not be a very serious matter if Angstrom's relative wave-lengths were exact, which they are not."

"In the Mechanical Section I heard part of a strangely-timed paper (it rained most of the time we were in Manchester) on "Drought," by ——— Symonds. He was followed by a blunt-spoken old man who seemed to command much respect. He said that despite present skies he could remember a water-drought in England equal to that of Elijah's time."

"Looked into several of the Sections. President Newton of the Biological is a large man with short side whiskers and grey hair and eye-brows—pleasant looking and dressed in a business suit. Some of the papers were very poorly read. Canon Taylor's style in Section H., Anthropology, was so much like poor church reading here that I could not listen with any comfort to his mouthed sentences, and so left."

"Heard Preece, the electrician, report his experiments in telegraphy without wires. From stations on both sides of the river Severn he could secure weak responsive currents. Professor

Boyd Dawkins of the Geological Section spoke of the project of a Channel Tunnel. No water to hurt in the experimental gallery opened 5 years ago—only 1/3 of a gallon per minute. The gray chalk is the protecting stratum, and it extends over the channel bottom all the way to France. The motive for constructing the tunnel is a commercial one; the objection to it is of course the military one: and by the time Professor Dawkins began an attempt to minimize the latter he was incontitently shut off by Woodward, President of the Section. Dawkins is a pale-faced nervous mannered man, with light hair and moustache."

Manchester, Sept. 14th.—"To the Sessions of the Iron and Steel Institute now in session here. I was given free admission to all the sessions of this Institute. I simply told them I was an American, and interested in learning what they were doing: a card of entrance was handed me forthwith. The mayor of the city gave the members a hearty address of welcome. Alluding to Sir Henry Bessemer, who sat near by, he said, in the millions saved to the kingdom per year through his processes we see fulfilled the saying 'no man liveth to himself.' The Bessemer medal for improved product of mild steel was conferred on James Riley of Glasgow—a proud day for that fresh-looking, fine fellow, who looked as if there might be still much ahead for him. Sir Lothian Bell gave a paper on some process of improved production, chemically considered. He is a fine-looking, bald headed, white-whiskered man, with darker moustache. He commanded strict attention on the part of the whole assembly."

The Institute continued in session for several days. Sir Henry Bessemer was to be seen day by day sitting upon the platform in his skull cap. He looks some 60 years of age; has rather heavy features and a dark complexion. He has the proud distinction of seeing the fruits of his labors and of enjoying his honors during life.

"Among the remarks I heard at the meetings was one that the output of their largest furnaces is about 1,000 tons of iron per day, while the same in America reach 2,000 tons. Also that by the overstrained application of the doctrine of free trade the British producer can be nndersold with the greatest ease. Belgian iron is brought over for important enterprises, and is furnished at a rate destructive to home industry. 'So much for the wisdom of our statesmen.' (Hear, hear, Chamberlain)."

London, Oct. 25th.—"Called at the rooms of the Royal Astronomical Society, and was shown by the librarian, to whom I had a letter of introduction from Lord McLaren of Edinburgh, many

fine photographs of the stars made by Mr. Roberts of Liverpool, and still better ones by Paul and Prosper Henry of Paris. The latter use a specially adjusted refractor and secure marvellous definition. Looked at very closely one could see a three fold image of each star (in triangular position), purposely so taken to distinguish even the faintest star from an accidental spot on the plate or film. Small companion stars could be seen, just like a satellite of Jupiter trembling on the rim of the primary. The asteroid Sappho was shown taken by short exposures a few minutes apart, producing a linear image, while the fixed stars were round. After a two days' interval it was to be sought among a totally different group of stars. The best photo of a nebula was by Mr. A. Common. I was very well received by Mr. Wesley, the Librarian, and given an invitation to the meeting of the Royal Astronomical Society, Nov. 11th, coming."

London, Nov. 11th.—"Went to the meeting of the Royal Astronomical Society at Burlington House at 8 P. M. Papers were read on the albedo of Jupiter's satellites, with notes of experiments to show that all the changes in the apparent light of these bodies can be obtained by artificial means, of lesser bodies with varying light made to transit other and larger bodies with greater illumination. Captain Noble, a middle-aged, sanguine looking man, read a paper showing how far out he had been in taking the ordnance survey maps as guide to the position of his observatory—some 500 feet."

"Mr. Turner, of Greenwich Observatory, read a paper on Personal Equation, showing the difference between four observers proved by an arrangement to test their electric records, by means of a true electric record, just as the dummy star crossed the central wire. On the average, though somewhat out, the observers were within 1/10 of a second of time. To secure absolutely trustworthy results the young men concerned did not know they were then being tested."

"Professor Pritchard of Oxford followed, with his notes on photography as a means of obtaining parallax. Said he had found both components of 61 Cygni to have a parallax of about 1/10 of a second of arc by his method. Had tried Mu Cassiopeæ and Polaris and obtained decided results of about .04 and .05. Had lessened the time with about the same result, and now believes that by this method five nights only, twice a year, will be sufficient by which to determine the parallax of untried stars with more accuracy than has been obtained in the case of those heretofore determined. The negative results of Bessel in 1837,

and the approximate results of Struve in 1856, only give him the greater confidence in the new method, as these are both in harmony with his positive results. He now takes two exposures of a few minutes each of the star under examination and of the test star, and measures the distance of their places with the micrometer applied to their photographic images. In one case his results fell right between those of Bessel and Struve—and after many tests. Pritchard says it is more important to get a nearly correct parallax of many stars than a better one of but a few, and thinks his method will furnish them down to 1/20 of a second."

"Professor Christie, now Astronomer Royal, was present. He looks more like a farmer, with his full hearty face, than one so at the front in science. It was he who invented the personal equation test machine. The Society have a fine room, the walls adorned with prints and photos of the Moon and other astronomical objects. Photographs by Pickering and Roberts were shown. Some new members were proposed, two from America endorsed by Lewis Swift."

DR. D. K. PEARSONS, THE CHRISTIAN PHILANTHROPIST.

W. W. PAYNE.

It is a rare thing for this publication to turn aside from its chosen field to consider other topics, however worthy in themselves, if they are but remotely connected with the science of astronomy; yet we have made some exceptions to this rule; and our present theme is an important one for which we offer no further apology than to say that the princely gifts of this living benefactor have founded one new astronomical observatory and indirectly aided several others by giving to the colleges to which they belong.

Dr. D. K. Pearsons has long been a resident of Hinsdale, Ill., one of the cleanest and the most attractive of the suburbs of the great city of Chicago. April 14 he passed his eighty-fourth birthday in perfect health and in buoyancy of spirit that are very remarkable for his years. His intelligent face, his sharp eye, his plain speech, his keen sense of the true and the false and his scorn that withers every shame without ceremony are traits of the man for scores of years; and these same traits have ripened into the habits of a life that are so simple, so severely regular and so

strictly frugal as to make him the observed and the unique man among the very few like him in a whole generation. It is indeed refreshing to find one man in a thousand that has character and will power enough to put the things which he knows are right and best for him, intp his daily living, and to carry them steadily and faithfully on with him throughout a long and busy life to its very end. Such an example of mature physical powers, that may easily reach the hundredth year limit, is certainly an object lesson for young people now-a-days.

Interesting and profitable as it is, this part of our theme is not that part of it which appeals to us most strongly. It is rather the work of Dr. Pearsons for more than fifty years as a Christian philanthropist. Dr. Pearsons has always been a successful business man, and his benevolence, as time has gone on, has been greatly varied and most intelligently generous in every way. He has given to the needs of missionary societies, hospitals, churches, theological seminaries, the Young Men's Christian Association and many other worthy objects; but above all and beyond all he has been the friend of the Christian college in a most remarkable way. Those who have been in the great wave of college influence and enthusiasm, set in motion by his large, recent gifts, very well know that there is not another case like it in the history of this country. Some day hence, somebody will write a history of what this man has done, and will do, in the next decade of years, for the Christian college. If that history is truly told it will picture one of the noblest monuments to the memory of Dr. Pearsons that ever comes to the lot of fortune's favored sons.

When a man has the courage and the heart to take on his shoulders the needs and the care of thirty different colleges, and to meet their pressing wants and promises, with reasonable conditions, to give them more than 4,000,000 dollars of his own money, a type of philanthropy is shown that is certainly very remarkable of its kind. More than this, because Dr. Pearsons' gifts are so planned that these same colleges shall receive an additional amount of about 9,000,000 dollars to make his own available, it is evident that the wisdom and foresight of his plans are an indication of a business sagacity that might be copied in many other things with beneficent results.

A further notable feature in the character of this man's benevolence is the fact that it is all carefully planned beforehand; sometimes for years, and then the plans so matured are carried out systematically to the end, even in regard to the details of the giving by others which are required to treble or quadruple his

own conditional promises. This phase of his philanthropic work is not a fad or a spasm in declining age, but it has been a genuine business habit covering more than fifty years of the best part of his active life. If we follow the record back to 1854, even then this noble work was going on, and the sum total of this young man's useful gifts had reached a quarter of a million of dollars.

Now all this points plainly to gifted leadership in wise thinking and in large, benevolent doing for two generations past; for men that succeed, from small beginnings, must think and must act on a large scale to reach such a level of high merit and to maintain it with conspicuous honor for a long life.

But one of the surest tests of the value of a good and useful life is the esteem in which it is held where it is best known. As Dr. Pearsons' birthday came last month, many congratulations were sent South, where he has been spending the winter, in search of him, and some waylaid him on his way home.

The "Hinsdale Doings," extends its greetings to Dr. Pearsons at his recent home-coming in very fitting words. It says: "Hinsdale has just cause to be proud of her illustrious citizen. His reputation is national, and the honor in which his name is held reflects some of its glory on our quiet, conservative little town. The presence of so strong a character among us—one so devoted to the uplift of American youth—so unwavering in his steadfast purpose to help only what is best, should make us grateful to own him as a friend; should make us proud and happy."

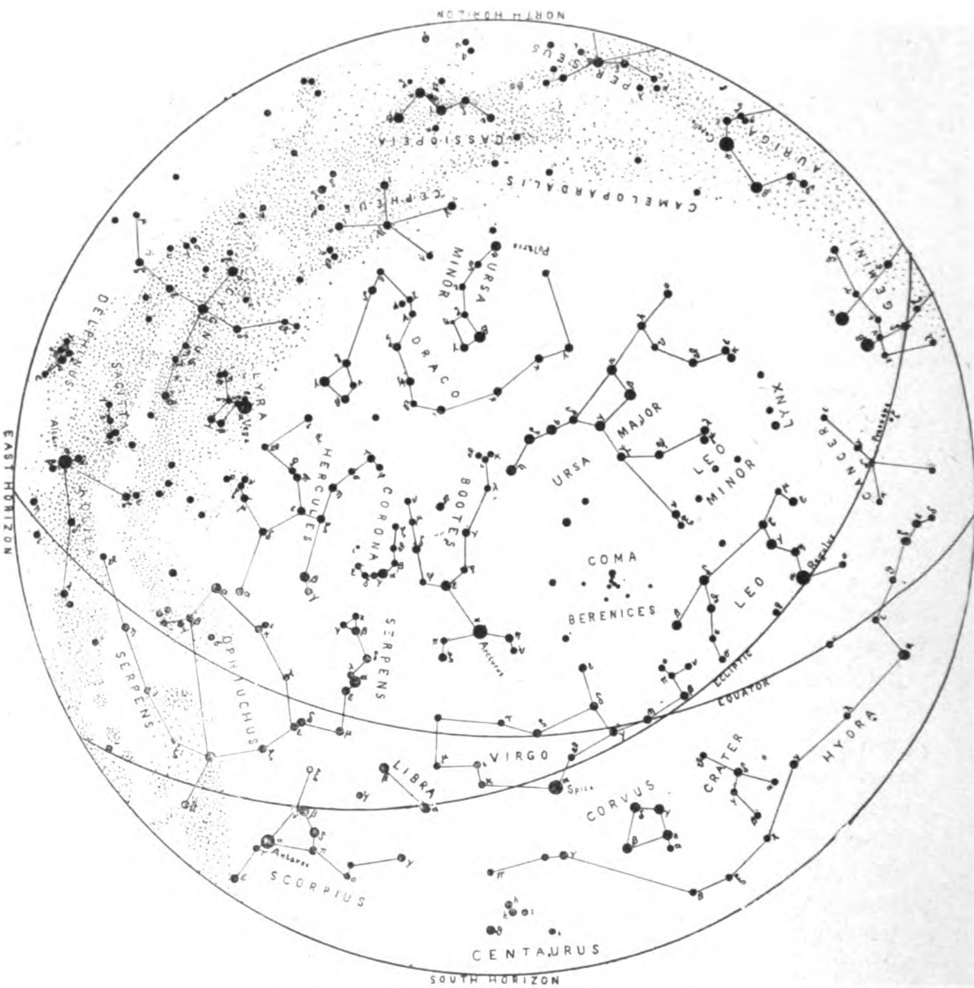
What a real and lasting joy it must be to a man to be thought of in this way. What a pleasure to know that so many friends remember him so truly and so kindly. There can be no joy on Earth more royal, more satisfying, more uplifting than that which comes from the consciousness of large-hearted benevolence, well placed to meet the real and the pressing needs of the present and the future. The great joy that has come to Dr. Pearsons for his princely giving is richly deserved. Let that joy abound more and more, and let it fill and overflow all his coming years, in unrestrained way as a bright promise of better things to come.

In the frontispiece to this number we have tried, with painstaking care, to represent Dr. Pearsons, as he now looks, that our readers may see a picture of the face of the man so many people delight to honor.

PLANET NOTES FOR JUNE.

H. C. WILSON.

Mercury in June will be morning star visible toward the northeast an hour before sunrise during the first two weeks. The planet will be at greatest elongation, west from the Sun 23° 46′, on June 8.



THE CONSTELLATIONS AT 9 P. M. JUNE 1, 1904.

Venus is coming in close to superior conjunction, being only about 11° west from the Sun at the beginning of the month. Conjunction will not occur until July 7. Just how long the planet may be seen with the naked eye during this

month is an open question. Probably where the atmosphere is transparent near the eastern horizon the planet may be followed during the greater part of the month.

Mars having passed conjunction with the Sun on May 30 will not be visible during June. A conjunction of Mars with Venus will occur on June 18, when however neither planet can be readily seen.

Jupiter is morning star rising about three to four hours before the Sun and being near the meridian about 8 o'clock in the morning. Jupiter is now north of the equator, in the constellation Pisces and will be in good position for observation during the summer.

Saturn is in Capricornus, near the meridian toward the south at 4 A. M. The rings of Saturn are inclined about 16° to the line of sight so that their details of structure may be well seen during this summer.

Uranus will be at opposition June 19 so that this month and the next will afford the best opportunities for the study of this planet during the year.

Neptune is behind the Sun, being at conjunction June 27.

The Moon.

(Central Standard Time at Northfield. Local Time 13m less.)

1904	Phases.	Rises. h m	Sets. h m
June 6	Last Quarter	12 42 A. M.	12 28 P. M.
13	New Moon	4 36 "	7 40 "
19-20	First Quarter	11 10 "	12 07 A. M.
27-28	Full Moon	7 44 P. M.	5 28 "

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N pt. °	EMERSION. Washington M. T. h m	Angle f'm N pt. °	Duration. h m
June 9	25 Arietis	7.3	16 38	82	17 45	234	1 7
22	96 Virginis	6.5	6 43	122	8 4	288	1 21
24	49 Libræ	5.6	8 12	89	9 32	306	1 20
30	18 Aquarii	5.4	13 31	3	14 4	320	0 33

COMET AND ASTEROID NOTES.

New Comet *a* 1904 (Brooks).—A new comet was discovered by W. R. Brooks, of Geneva, N. Y., on the night of April 16 at $9^h 55^m$ E. S. time. It was then in the northern part of the constellation Hercules and moving in a northwesterly direction. The comet has since been found on the photographs at Harvard College Observatory taken on the nights of March 11, 15, April 1, 2, 5, 13 and 16, prior to the announcement of discovery by Professor Brooks. These early photographs will be of great value in giving a quick determination of the comet's orbit.

As seen at Goodsell Observatory on the night of April 18, the comet is easily visible, but not at all conspicuous, with a 5-inch telescope. With the 16-inch

telescope it reveals the characteristic features of a small bright comet: a nucleus of about the 10th magnitude, a rounded head or coma of perhaps 2′ diameter and a faint, spreading tail about 10′ long.

The following observations are at hand, most of them having been transmitted by telegraph through the courtesy of Harvard College Observatory:

Greenwich M. T.	R. A.			Decl.			Observer.
d	h	m	s	°	′	″	
Mar. 11.872	18	2	10	+17	28		H. C. O.
" 15.899	17	56	9	20	21		"
Apr. 1.889	17	26	45	34	29		"
" 2.826	17	25	30	35	3		"
" 5.850	17	20	20	37	7		"
" 13.825	17	4	4	42	28		"
" 16.618	16	58	10	44	10		Brooks.
" 16.855	16	56	29	44	23		H. C. O.
" 16.870	16	56	32	44	22		"
" 17.552	16	55	5	44	48		Brooks.
" 17.6579	16	55	50.18	44	51	30.1	Naval Obs.
" 17.6592	16	55	49.6	44	51	32	Seares.
" 17.6661	16	55	48.87	44	51	50.1	Naval Obs.
" 17.7132	16	55	40.8	44	53	37	Aitken.
" 17.8717	16	55	14.51	44	59	37.6	Naval Obs.
" 18.6289	16	53	7.6	45	27	56	Seares.
" 18.6891	15	52	57.5	45	30	13	Wilson.
" 20.6677	16	47	18.4	+46	42	51	"

The positions marked H. C. O., including five before the comet was discovered, are derived from the Harvard photographs. The positions are for 1855. They are only approximate and depend on Durchmusterung places of the stars. Two photographs taken at Harvard on April 16, with an objective prism, show a nearly continuous spectrum with a slight increase in light at two points, so that the distribution of light seems to be the same as in a similar photograph of Comet VII, 1898.

The following elliptic elements, communicated by telegram from Professor A. O. Leuschner, have been computed by Ralph Curtiss and Sebastian Albrecht from observations on April 17, 18 and 19. They represent the general path of the comet as derived from the Harvard photographs fairly well.

Epoch 1904 Apr. 18.62 Gr. M. T.

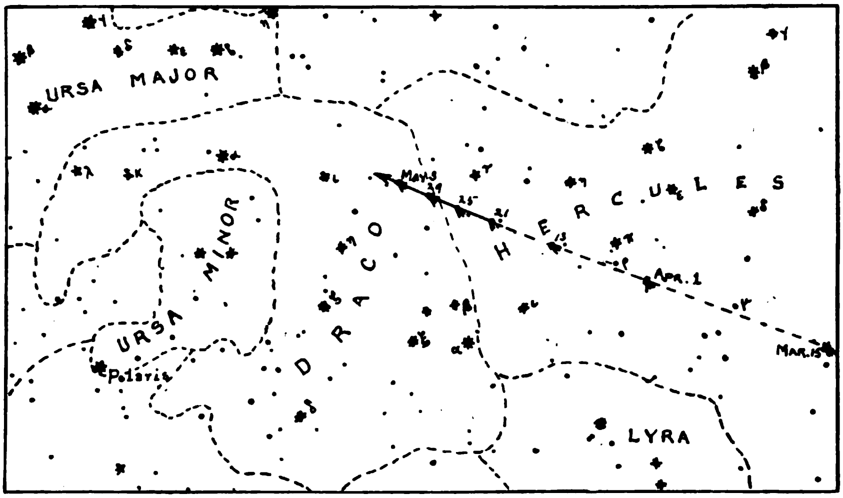
$M = 159°\ 08'$	$q\ (a?) = 1.7177$
$\omega = 258\ \ 57$	$e = 0.1773$
$\Omega = 272\ \ 13$	Period = 3.02 years.
$i = 126\ \ 39$	

From these elements the following ephemeris is computed:

Gr. M. T.	R. A.			Decl.		Brightness.
	h	m	s	°	′	
Apr. 21.5	16	44	32	+47	13	0.98
25.5	16	31	08	49	30	
29.6	16	16	08	51	34	
May 3.5	15	59	44	+53	22	0.88

The diagram shows that the comet was in the northern part of the constellation Hercules when discovered and that it passed through a large part of that

constellation during the period covered by the. Harvard photographs. During May it will pass through a part of Draco into Ursa Major.



PATH OF COMET *a* 1904, BROOKS.

Parabolic elements were computed by Professor Miller from observations on Apr. 16, 17 and 18, but these appear to be seriously in error and so will not be given here.

Definitive Orbit of Comet 1898 X.—In *A. N.* 3934 Mr. S. Scharbe, of Jurjew-Dorpat, gives the following elements of the comet 1898 X, based upon 266 observations combined into six normal places.

ELEMENTS ON COMET 1898 X.

	Elliptic	Parabolic	
Osculation	Nov. 5.0, 1898	Nov. 5.0, 1898	
$T =$	1898 Nov. 23, 195124	Nov. 23, 189594 Berlin	
$\omega =$	123° 32′ 23″.70	123° 31′ 53″.96	1898-0
$\Omega =$	96 18 12 .46	96 18 14 .47	1898-0
$i =$	140 20 57 .50	140 20 51 .52	1898-0
$\log q =$	9.8785038	9.8785281	
$\epsilon =$	0.9997421	1.0000000	

The elliptic elements represent the observations slightly better than the parabolic, but not enough better to give a decisive choice between the two sets of elements.

Discovery of Comet Brooks—*a* 1904.—On the evening of April 16 at 9:50 Standard time I discovered a comet in the constellation Hercules. Its position at discovery was R. A. $16^h\ 58^m\ 10^s$; declination north 44° 10′.

A second observation was obtained on the evening of April 17, with a position in R. A. $16^h\ 55^m\ 5^s$; declination north 44° 48′, thus giving a daily motion of three-quarters of a degree in a northwest direction. The comet is a fairly bright telescopic one with a short tail.

WILLIAM R. BROOKS.

SMITH OBSERVATORY, Geneva, N. Y.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	Discovered at	Local M. T.	R. A.	Decl.	Mag.
			h m	h m	° ′	
1904 NJ	Wolf	Heidelberg	1904 Mar. 4	8 21 6	9 55.8	+ 6 58	14
1901 NK	"	"	1901 Jan. 17	14 3.8	12 28.1	24 54	11
1901 NL	"	"	1901 May 9	12 34.3	13 42.3	47 01	11
1902 NM	"	"	1902 Oct. 8	11 39.0	1 49.6	20 59	13
1904 NN	"	"	1904 Mar. 14	12 37.8	10 14.9	7 45	12.5
1904 NO	"	"	14	12 37.8	10 22.7	+ 12 47	13.2
1904 NP	"	"	14	14 50.8	12 33.8	— 0 17	12.0
1904 NQ	"	"	14	14 50.8	12 48.9	2 37	13.3
1904 NR	"	"	18	15 19.7	14 27.8	— 0 5	13.0
1904 NS	"	"	18	12 29.7	12 54.0	+ 8 1	12.5
1904 NT	"	"	18	12 29.7	13 00.9	+ 8 8	13.2

1904 NJ was found near the place of the lost planet (310) Margarita, but does not seem to be identical with it. 1901 NK and NL were found recently in examining old plates taken in 1901. 1902 NM was found while looking for old photographs of 1898 DW, with which planet the new asteroid 1903 NF was supposed to be identical. 1904 NP has been found to be identical with (255) Oppavia.

VARIABLE STARS.

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.6$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h		d	h		d	h		d	h
June	1	20	June	9	16	June	17	12	June	25	9
	2	23		10	19		18	15		26	12
	4	1		11	22		19	18		27	15
	5	4		13	1		20	21		28	18
	6	7		14	4		22	0		29	20
	7	10		15	7		23	3		30	23
	8	13		16	9		24	6			

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
June	1	10	June	9	11	June	17	12	June	25	13
	2	10		10	11		18	12		26	13
	3	10		11	11		19	12		27	13
	4	10		12	11		20	13		28	14
	5	11		13	12		21	13		29	14
	6	11		14	12		22	13		30	14
	7	11		15	12		23	13			
	8	11		16	12		24	13			

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with noon. The hours from 12 to 24 are those which occur in the night in the United States. To obtain Eastern Standard time subtract 5 hours; for Central Standard time subtract 6 hours, etc.]

U Cephei.

	d	h
June	3	8
	5	20
	8	8
	10	20
	13	7
	15	19
	18	7
	20	19
	23	7
	25	18
	28	6
	30	18

Z Persei.

	d	h
June	1	6
	4	7
	7	9
	10	10
	13	11
	16	13
	19	14
	22	15
	25	17
	28	18

Algol.

	d	h
June	3	19
	6	16
	9	13
	12	9
	15	6
	18	3
	21	0
	23	21
	26	18
	29	15

RR Puppis.

	d	h
June	3	20
	10	6
	16	16
	23	2
	29	13

V Puppis.

	d	h
June	2	5
	3	16
	5	3
	6	14
	8	1
	9	12
	10	23
	12	10
	13	21
	15	8
	16	18

V Puppis.

	d	h
June	18	5
	19	16
	21	3
	22	14
	24	1
	25	12
	26	23
	28	10
	29	21

S Cancri.

	d	h
June	8	17
	18	5
	27	16

S Antliæ.

Period $7^h\ 46^m.8$.

	d	h
June	1	7
	2	6
	3	6
	4	5
	5	4
	6	4
	7	3
	8	2
	9	2
	10	1
	11	0
	12	0
	12	23
	13	22
	14	22
	15	21
	16	20
	17	20
	18	19
	19	18
	20	18
	21	17
	22	16
	23	16
	24	15
	25	14
	26	14
	27	13
	28	12
	29	12
	30	11

S Velorum.

	d	h
June	3	2
	9	1
	14	23
	20	21
	26	20

W. Urs. Maj.

Period $4^h\ 0^m.2$

June 1-13 7^h
14-31 8

RR Velorum.

	d	h
June	1	1
	2	21
	4	18
	6	14
	8	11
	10	7
	12	4
	14	0
	15	21
	17	17
	19	14
	21	10
	23	7
	25	3
	27	0
	28	20
	30	17

Z Draconis.

	d	h
June	1	12
	2	21
	4	5
	5	14
	6	22
	8	7
	9	15
	11	0
	12	9
	13	17
	15	2
	16	10
	17	19
	19	4
	20	12
	21	21
	23	5
	24	14
	25	22
	27	7
	28	16
	30	0

δ Librae.

	d	h
June	1	16
	4	0
	6	8
	8	16
	11	0
	13	7

δ Libræ.

	d	h
June	15	15
	17	23
	20	7
	22	15
	24	23
	27	7
	29	14

U Coronae.

	d	h
June	2	1
	5	12
	8	22
	12	9
	15	20
	19	7
	22	18
	26	5
	29	16

R Aræ.

	d	h
June	4	1
	8	11
	12	22
	17	8
	21	18
	26	4
	30	14

U Ophiuchi.

	d	h
June	1	16
	2	12
	3	8
	4	5
	5	1
	5	21
	6	17
	7	13
	8	9
	9	5
	10	1
	10	22
	11	18
	12	14
	13	10
	14	6
	15	2
	15	22
	16	18
	17	15
	18	11
	19	7
	20	3
	20	23
	21	19
	22	15

U Ophiuchi.

	d	h
June	23	12
	24	8
	25	4
	26	0
	26	20
	27	16
	28	12
	29	8
	30	5

Z Herculis.

	d	h
June	1	19
	3	22
	5	19
	7	22
	9	19
	11	22
	13	19
	15	22
	17	19
	19	21
	21	18
	23	21
	25	18
	27	21
	29	18

RS Sagittarii.

	d	h
June	2	8
	4	18
	7	4
	9	14
	12	0
	14	10
	16	20
	19	6
	21	16
	24	2
	26	12
	28	22

RX Herculis.

	d	h
June	1	5
	2	2
	2	23
	3	21
	4	18
	5	16
	6	13
	7	10
	8	8
	9	5
	10	2
	11	0
	11	21
	12	18

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis.

	d	h
June	13	16
	14	13
	15	10
	16	8
	17	5
	18	2
	19	0
	19	21
	20	18
	21	16
	22	13
	23	10
	24	8
	25	5
	26	2
	27	0
	27	21
	28	19
	29	16
	30	13

RV Lyræ.

	d	h
June	1	12
	5	2
	8	16
	12	7
	15	21

RV Lyræ.

	d	h
June	19	12
	23	2
	26	16
	30	7

U Sagittæ.

	d	h
June	1	12
	4	21
	8	6
	11	15
	15	0
	18	9
	21	18
	25	4
	28	13

SY Cygni.

	d	h
June	6	18
	12	18
	18	18
	24	18
	30	19

SW Cygni.

	d	h
June	2	12
	7	2

SW Cygni.

	d	h
June	11	15
	16	5
	20	19
	25	9
	29	22

UW Cygni.

	d	h
June	4	3
	7	14
	11	1
	14	12
	17	23
	21	10
	24	20
	28	7

W Delphini.

	d	h
June	3	20
	8	16
	13	11
	18	7
	23	2
	27	21

VV Cygni.

	d	h
June	1	23
	3	11

VV Cygni.

	d	h
June	4	22
	6	10
	7	21
	9	8
	10	20
	12	7
	13	19
	15	6
	16	18
	19	17
	21	4
	22	16
	24	3
	25	14
	27	2
	28	13
	30	1

VW Cygni.

	d	h
June	3	7
	11	18
	20	4
	28	15

Y Cygni.

	d	h
June	2	2
	3	17
	5	2
	6	17
	8	2
	9	16
	11	1
	12	16
	14	1
	15	16
	17	1
	18	16
	20	1
	21	16
	23	1
	24	16
	26	1
	27	16
	29	1
	30	16

UZ Cygni.

	d	h
June	20	19

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
June	1	16	June	8	20	June	16	0	June	23	4
	2	17		9	21		17	0		24	4
	3	17		10	21		18	1		25	5
	4	18		11	22		19	1		26	5
	5	18		12	22		20	2		27	6
	6	19		13	23		21	3		28	6
	7	20		14	23		22	3		29	7
										30	7

Ephemerides of Long Period Variables.—In *A. J.* 560 Dr. S. C. Chandler gives ephemerides of the maxima occurring between 1903 and 1910, for all the long period variable stars contained in his third catalogue, computed from the revised elements given in *A. J.* 553.

Secondary Minimum of UZ Cygni.—A letter has been received at the Harvard College Observatory from Professor Kreutz at Kiel Observatory, stating that "the star of Algol type UZ Cygni (BD. + 43°4101) has a bright secondary minimum May 3d. Hartwig."

Harvard College Observatory Astronomical Bulletin, No. 152, Apr. 21, 1904.

Variable Stars of Short Period not of the Algol Type.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
Y Sagittarii	June 1	10	June 3	5	δ Cephei	June 15	18	June 17	3
V Velorum	1	13	2	12	η Aquilae	15	21	18	6
η Aquilæ	1	13	3	22	U Vulpeculae	16	0	18	3
R Crucis	1	16	3	1	S Muscae	16	3	19	14
S Triang. Austr.	1	17	3	19	S Crucis	16	4	17	16
V Centauri	1	19	3	6	T Crucis	16	17	18	18
S Sagittæ	1	22	5	8	T Monocerotis	16	21	24	19
S Crucis	2	2	3	14	β Lyræ	17	3	20	10
S Normae	2	5	6	15	RV Scorpii	17	7	18	17
T Vulpeculae	2	8	3	17	Y Ophiuchi	17	13	23	18
κ Pavonis	2	9	6	4	T Velorum	17	18	19	3
T Crucis	3	6	5	7	V Centauri	18	6	19	17
T Velorum	3	20	5	5	S Sagittae	18	16	22	2
SU Cygni	3	20	5	4	Y Sagittarii	18	17	20	12
β Lyræ	4	5	7	12	X Sagittarii	18	19	21	16
X Sagittarii	4	19	7	16	R Crucis	19	3	20	12
δ Cephei	5	1	6	10	U Aquilae	19	3	21	7
U Aquilae	5	2	7	7	SU Cygni	19	6	20	14
RV Scorpii	5	4	6	14	V Carinae	19	12	21	16
W Virginis	5	20	14	1	V Velorum	20	1	21	0
V Velorum	5	22	6	21	T Vulpeculae	20	2	21	11
V Carinae	6	4	8	8	U Sagittarii	20	3	23	2
W Sagittarii	6	6	9	6	κ Pavonis	20	13	24	8
S Muscae	6	11	9	22	S. Triang. Austr.	20	16	22	18
U Sagittarii	6	15	9	14	S Crucis	20	20	22	8
T Vulpeculae	6	18	8	3	δ Cephei	21	3	22	12
S Crucis	6	19	8	7	W Sagittarii	21	10	24	10
V Centauri	7	7	8	18	S Normae	21	17	26	3
Y Sagittarii	7	10	9	5	T Velorum	22	9	23	18
R Crucis	7	12	8	21	η Aquilae	23	1	25	10
SU Cygni	7	16	9	9	SU Cygni	23	2	24	10
S Trianguli Austr.	8	1	10	3	W Virginis	23	3	31	8
U Vulpeculae	8	1	10	4	RV Scorpii	23	9	24	19
X Cygni	8	6	14	11	V Velorum	23	9	24	8
T Velorum	8	11	9	20	T Crucis	23	10	25	11
η Aquilae	8	17	11	2	TX Cygni	23	10	28	13
TX Cygni	8	17	13	20	β Lyrae	23	14	26	16
T Crucis	9	23	12	0	V Centauri	23	18	25	5
V Velorum	10	7	11	6	U Vulpeculae	24	0	26	3
S Sagittæ	10	7	13	17	T Vulpeculae	24	12	25	21
δ Cephei	10	9	11	18	Y Sagittarii	24	12	26	7
β Lyræ	10	16	13	18	X Cygni	24	15	30	20
T Vulpeculae	11	5	12	14	R Crucis	24	23	26	8
RV Scorpii	11	6	12	16	S Crucis	25	13	27	1
κ Pavonis	11	11	15	6	S Muscae	25	18	29	5
S Crucis	11	11	12	23	X Sagittarii	25	20	28	17
SU Cygni	11	13	12	21	U Aquilae	26	4	28	8
X Sagittarii	11	19	14	16	V Carinae	26	6	28	10
S Normae	11	23	16	9	δ Cephei	26	12	27	21
U Aquilae	12	3	14	7	U Sagittarii	26	21	29	20
V Centauri	12	19	14	6	SU Cygni	26	22	28	6
V Carinae	12	20	15	0	T Velorum	27	0	28	9
Y Sagittarii	12	23	14	18	S Triang.Austr.	27	0	29	2
T Velorum	13	2	14	11	S Sagittae	27	1	30	11
R Crucis	13	7	14	16	V Velorum	27	17	28	16
U Sagittarii	13	11	16	10	κ Pavonis	28	15	32	10
W Sagittarii	13	20	16	20	T Vulpeculae	28	23	30	8
S Triang. Austr.	14	8	16	10	W Sagittarii	29	1	32	1
V Velorum	14	16	15	15	V Centauri	29	6	30	17
SU Cygni	15	9	16	7	RV Scorpii	29	10	30	20
T Vulpeculae	15	15	17	10	β Lyrae	30	1	33	8

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
T Crucis	June 30	4	June 32	1	η Aquilae	June 30	6	June 32	15
S Crucis	30	5	31	17	SU Cygni	30	18	32	2
Y Sagittarii	30	6	32	1	R Crucis	30	19	32	4

Approximate Magnitudes of Variable Stars Apr. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn
T Androm.	0 17.2	+ 26 26	*s*	R Camel.	14 25.1	+ 84 17	10*i*
T Cassiop.	0 17.8	+ 55 14	8.8*d*	R Bootis	14 32.8	+ 27 10	7.0*i*
R Androm.	0 18.8	+ 38 1	7.5*d*	S Librae	15 15.6	— 20 2	12*d*
S Ceti	0 19.0	— 9 53	*s*	S Serpentis	15 17.0	+ 14 40	13*i*
S Cassiop.	1 12.3	+ 72 5	13*d*	S Coronae	15 17.3	+ 31 44	7.5*d*
R Piscium	1 25.5	+ 2 22	*s*	S Urs. Min.	15 33.4	+ 78 58	10.5*d*
R Trianguli	1 31.0	+ 33 50	11.5*d*	R Coronae	15 44.4	+ 28 28	5.6
U Persei	1 52.9	+ 54 20	11.5*d*	V "	15 45.9	+ 39 52	9·5*d*
R Arietis	2 10.4	+ 24 36	13*f*	R Serpentis	15 46.1	+ 15 26	12*i*
o Ceti	2 14.3	— 3 26	*s*	R Herculis	16 1.7	+ 18 38	14*d*
S Persei	2 15.7	+ 58 8	11	R Scorpii	16 11.7	— 22 42	9
R Ceti	2 20.9	— 0 38	*s*	S "	16 11.7	— 22 39	12
U "	2 28.9	— 13 35	*s*	U Herculis	16 21.4	+ 19 7	8*d*
R Persei	3 23.7	+ 35 20	10*i*	W Herculis	16 31.7	+ 37 32	10*d*
R Tauri	4 22.8	+ 9 56	12.0*d*	R Draconis	16 32.4	+ 66 58	10.3*d*
S "	4 23.7	+ 9 44	12.0*d*	S Herculis	16 47.4	+ 15 7	13*d*
R Aurigæ	5 9.2	+ 53 28	8.0*d*	R Ophiuchi	17 2.0	— 15 58	13*d*
U Orionis	5 49.9	+ 20 10	7.5*i*	T Herculis	18 5.3	+ 31 0	8.8*i*
R Lyncis	6 53.0	+ 55 28	12*i*	R Scuti	18 42.2	— 5 49	*u*
R Gemin.	7 1.3	+ 22 52	13.2*d*	R Aquilae	19 1.6	+ 8 5	8*i*
S Canis Min.	7 27.3	+ 8 32	8.8*d*	R Sagittarii	19 10.8	— 19 29	*u*
R Cancri	8 11.0	+ 12 2	11*d*	S "	19 13.6	— 19 12	*u*
V "	8 16.0	+ 17 36	8*i*	R Cygni	19 34.1	+ 49 58	12*d*
S Hydrae	8 48.4	+ 3 27	10.7*d*	RT "	19 40.8	+ 48 32	10*i*
T "	8 50.8	— 8 46	9*d*	X "	19 46.7	+ 32 40	11*d*
R Leo. Min.	9 39.6	+ 34 58	12*d*	S Cygni	20 3.4	+ 57 42	*f*
R Leonis	9 42.2	+ 11 54	8.0*i*	RS "	20 9.8	+ 38 28	8
R Urs. Maj.	10 37.6	+ 69 18	13.5	R Delphini	20 10.1	+ 8 47	*f*
R Comae	11 59.1	+ 19 20	*f*	U Cygni	20 16.5	+ 47 35	7.5*i*
T Virginis	12 9.5	— 5 29	10.5*d*	V "	20 38.1	+ 47 47	9.5*i*
R Corvi	12 14.4	— 18 42	10.0*d*	T Aquarii	20 44.7	— 5 31	*u*
Y Virginis	12 28.7	— 3 52	11.3*d*	R Vulpec.	20 59.9	+ 23 26	10
T Urs. Maj.	12 31.8	+ 60 2	12.2*i*	T Cephei	21 8.2	+ 68 5	6.5*d*
R Virginis	12 33.4	+ 7 32	10.8*d*	S "	21 36.5	+ 78 10	7
S Urs. Maj.	12 39.6	+ 61 38	8.6*i*	S Lacertae	22 24.6	+ 39 48	*s*
U Virginis	12 46.0	+ 6 6	10.8*i*	R "	22 38.8	+ 41 51	*s*
V "	13 22.6	— 2 39	13*d*	S Aquarii	22 51.8	— 20 53	*s*
R Hydrae	13 24.2	— 22 46	4.5	R Pegasi	23 1.6	+ 10 0	*s*
S Virginis	13 27.8	— 6 41	13*d*	S "	23 15.5	+ 8 22	*s*
R Can. Ven.	13 44.6	+ 40 2	9.5*i*	R Aquarii	23 38.6	— 15 50	*s*
S Bootis	14 19.5	+ 54 16	13*d*	R Cassiop.	23 53.3	+ 50 50	7.5*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, McCormick, and Harvard Observatories.

49.1903 Orionis.—This is one of the variables discovered by Dr. Max Wolf in the Great Nebula of Orion (see POPULAR ASTRONOMY, Volume 12, page 62). It is interesting on account of being the brightest, with possibly the exception of T Orionis, of the seventy-one stars in this region whose variability appears certain from the Heidelberg and Harvard photographs. A chart of the region is given by Wolf in *A. N.* 3935.

Five observations of this star made with an equalizing wedge photometer attached to the 58.4 cm. (23-inch) refractor indicate a rapid variation and a large range. On March 9, I observed it 4.13 magnitudes fainter than BD. — 4°1216, $9^m.5$, but on April 14 it was 0.48 magnitudes brighter than the same star, thus making an increase of 4.61 magnitudes in 36 days, or at the rate of 0.13 magnitude a day. A slightly red color was noted at the last three observations.

ZACCHEUS DANIEL.

PRINCETON, New Jersey, 1904 April 18.

New Variable 9.1904 Orionis.—In *A. N.* 3935 Professor W. Luther states that the star 4^s following the variable U Orionis, No. 41 of Hagen's charts, to which Professor Hagen assigns the magnitude 10.9, is also variable to the extent of about one magnitude. It was unusually faint on the dates 1898 Jan. 17, 1901 Feb. 7, 1902 Dec. 5, 1903 Feb. 26 and 1904 Jan. 20. It was unusually bright on the dates 1903 Mar. 21 and 1904 Feb. 15. A period of 41.4 days would serve to represent these observations. The position of the star for 1855 is

R. A. $5^h\ 47^m\ 16.^s2$; Decl. + 20° 8.′7.

New Variable 10. 1904 Monoceros.—In *A. N.* 3935 Rev. T. D. Anderson announces a new variable near the star BD. +5° 1546. It was first seen early in 1902 (date not recorded), when the two stars were nearly equal in brightness, about 9.5 magnitude. On March 15, 1902, it was invisible with a three-inch refractor. Mr. Anderson searched for the star during the first three months of 1903 and during the present year but was unable to see it until March 9, when it was only 0.1^m or 0.2^m fainter than BD. +° 1546. The position of the star for 1855 is

R. A. $6^h\ 59^m\ 47^s$; Decl. + 5° 12.′7.

New Variable 11.1904 Orionis.—This new variable was found by Professor Wolf, of Heidelberg, on two photographic plates, taken on Jan. 10, 1904. Its position for 1900.0 is

R. A. $5^h\ 32^m\ 35^s.63$; Decl. — 1° 49′ 55″.4

From an examination of sixteen plates taken between Dec. 31, 1890, and Jan. 10, 1904, the variation seems to be from 11.0 to less than 14 magnitude. The period is not determined.

New Variable 12.1904 Geminorum.—This is also found by Professor Wolf. On a plate taken Mar. 20, 1904 it was about 10.0 magnitude, but upon earlier plates taken in 1891, 1892, 1902 and 1903 it was either invisible or only 13 or 14 magnitude. Its position for 1855 is

R. A. $6^h\ 38^m.1$; Decl. + 18° 47′.

New Variable 13.1904 Leonis.—Professor Wolf states that a star of the 12th magnitude was found on a plate taken Feb. 21, 1901, which is missing entirely from earlier photographs, as well as from others taken this year. Its position for 1900 is

R. A. 10^h 11^m $50^s.0$; Decl. + 12° 53′ 12″.

New Variable Star 14.1904 Cygni.—Professor W. Ceraski of Moscow announces this star in A. N. 3940. It was found upon photographic plates by Mme. L. Ceraski. Its position for 1855 is

R. A. 20^h $0^s.4$; Decl. + 58° 32′

and the variation is from 10.7 to 11.6 magnitude. The period is short, about 3.2 hours, and the light curve resembles that of the "cluster type" of variables.

Observations of Nova Persei.

Y.	M.	D.	H.	M.	J. Day.	Comparison.
1904	2	20	8	0	2416531	S1VV1½t
"	"	22	7	20	6533	S1VV2t
"	3	8	7	40	6548	S½VV2t
"	"	"	7	55	"	Var = S
"	"	12	8	20	6552	r1½VV1S
"	"	13	7	30	6553	S1½VV1t
"	"	16	7	25	6556	S½VV2t
"	"	17	7	5	6557	S½VV2½t
"	"	20	7	15	6560	S1VV1½t
"	"	23	9	35	6563	S½VV2t
"	"	24	7	5	6564	S1VV2t
"	"	28	7	20	6568	Var = S
"	"	29	7	20	6569	S½VV2½t
"	4	4	7	45	6575	S1VV1½t
"	"	5	8	0	6576	S½VV2½t
"	"	10	8	10	6581	S½VV2t
"	"	12	8	0	6583	S1VV1½t
"	"	16	7	40	6587	S½VV2t
"	"	17	7	30	6588	S½VV2½t
"	"	20	7	50	6591	S½VV2½t

This object does *not* vary much now. It has been nearly stationary for two months, except on the night of March 12 when it was about 2/10 of a magnitude brighter than normal.

F. E. SEAGRAVE.

GENERAL NOTES.

We expected confidently that this number of our publication would reach our foreign readers before the first of this month, but the new Linotype has been so balky that it has made us more work than the old ways of type-setting. We hope for better results next month.

Comet *a* 1904 (Brooks) has given observers something to do in getting the positions of the new visitor. Some of the places that have been sent us were far out of the way, and we have not used them. The apparent path of the comet among the stars elsewhere given is probably closely correct. The diagram of its orbit will be given next month.

Students' New Observatory at Berkeley.—In the last issue of the Publications of the Astronomical Society of the Pacific is found a cut illustrating the students' new observatory located at Berkeley, California. Its purpose is to supplement the instruction in astronomy given at the University of California, and from the description of it given by Professors Campbell and Leuschner the equipment seems to be admirably adapted to the end desired.

Those who have set this noble work forward and made the results already realized possible, are to be commended for their liberality and wise foresight in one of the most practical things that could be done for elementary astronomy.

The Companion of Algol.—The following interesting note on the Companion of Algol is given by Mr. J. E. Gore, F. R. A. S., in the Journal of the British Astronomical Association, Vol. XIV, No. 5.

"It is usually assumed that the companion of Algol is a dark body. But if by the term "dark" is meant a body resembling the Earth or even Jupiter, I fail to see there is any warrant for such an assumption. From spectroscopic observations Vogel found the diameter of Algol to be 1,074,000 miles, and its mass 4/9ths of the Sun's mass, and for the companion a diameter of 840,000 miles and a mass equal to 2/9ths of the Sun's mass. This result was obtained on the assumption that both compounds are of the same density—about one-third that of water. But it seems very difficult or impossible to suppose that a dark body of such a comparatively large mass—about 233 times the mass of Jupiter—could have so small a density, Jupiter's density being about 1.27, or over 3 times that of the Algol companion. As Jupiter has probably some inherent light of its own, it seems highly probable that the companion of Algol also shines by intrinsic light. Let us see what brightness the companion could have without sensibly affecting the observed light variation of Algol. Chandler finds for Algol a probable parallax of 0″.07. The Sun placed at the distance indicated by this parallax would, I find, be reduced to a star of 5.84 magnitude. Now the photometric magnitude of Algol being 2.31, it would be 3.53 magnitudes or nearly 26 times brighter than the Sun. Let us assume that the companion has this magnitude of 5.84. Then, when in the course of its orbital revolution round Algol, the companion is hidden behind the bright star, the normal light of Algol would be reduced by its 27th part. This means that the light of Algol would be diminished by about 0.04 magnitude, or from 2.31 to 2.35. This difference would not be perceptible to the naked eye, and could hardly be determined with certainty even with the most delicate photometer.

The spectrum of Algol is according to Professor Pickering, B. 8. A., that of Sirius being A. Comparing the two stars and assuming the surface brightness to be the same, I find a parallax of 0″.11 for Algol. This would reduce the Sun to a star of 4.84 magnitude, and if we suppose the Algol companion to have this brightness, then Algol would be 10.28 times brighter than the companion, and when the latter was hidden behind the bright star the light of Algol would be reduced from about 2.31 to 2.41, and even this difference could hardly be determined with certainty.

Observations by Plassmann and others seem to show some fluctuations in the light of Algol during its normal period, but to a greater extent than indicated by the above computations. If these observations are correct and the variations are due to the eclipse of the companion, then its brightness might be even greater than indicated above. But in that case the spectroscope would

probably show it. With a brightness of even the 7th magnitude, the companion could not be called a "dark body."

Ephemeris of Wolf's Comet 1884 III.—This ephemeris, given by Dr. Berberich in A. N. 3940, comes to hand too late to be put in its proper place under "Comet Notes." The comet is not due at perihelion until May 4, 1905, but then will be very unfavorably situated for observation. It may possibly be detected, with the aid of powerful telescopes, when near opposition during this summer. Opposition occurs on June 16, when the comet will be more than twice as far from the Earth as the Earth is from the Sun. The theoretical brightness of the comet during July will be almost equal to that which it possessed when last seen at the apparition in 1899. The elements depend upon the observations obtained at the first three apparitions of the comet, and the perturbations by the planets Jupiter, Saturn, Mars and Earth have been computed up to the end of the year 1904.

ELEMENTS.

Epoch:	1898 Aug. 22.0	1904 June 12.0 Berlin.
$M =$	6^c 58′ 10″.03	312° 52′ 22″.66
$\omega =$	172 52 26 .52	172 50 38 .22 } 1900.0
$\Omega =$	206 29 3 .03	206 28 59 .66 } 1900.0
$i =$	25 12 15 .36	25 14 40 .20 } 1900.0
$\phi =$	33 44 2 .97	33 48 59 .19
$\mu =$	518″.36643	520″.05191
$\log a =$	0.5569131	0.5559733

EPHEMERIS OF WOLF'S COMET 1884 III.

Berlin Midn. 1904.	R. A. h	m	s	Decl. °	′	log r.	log Δ.	Br.
May 7	18	2	21	+2	50.9	0.5298	0.4223	0.012
11	18	1	1	3	27.8			
15	17	59	21	4	4.2	0.5243	0.4044	0.014
19		57	23	4	39.7			
23		55	7	5	13.9	0.5186	0.3881	0.015
27		52	35	5	46.6			
31		49	48	6	17.4	0.5128	0.3739	0.017
June 4		46	47	6	46.0			
8		43	35	7	12.2	0.5069	0.3622	0.018
12		40	13	7	35.5			
☍ 16		36	45	7	55.7	0.5008	0.3533	0.020
20		33	14	8	12.6			
24		29	42	8	26.1	0.4946	0.3473	0.021
28		26	12	8	35.9			
July 2		22	48	8	42.2	0.4882	0.3444	0.022
6		19	32	8	44.8			
10		16	27	8	43.8	0.4817	0.3442	0.022
14		13	36	8	39.3			
18		11	0	8	31.6	0.4751	0.3466	0.023
22		8	42	8	20.7			
26		6	45	8	6.9	0.4683	0.3510	0.023
30		5	8	7	50.6			
Aug. 3		3	53	7	31.8	0.4613	0.3570	0.023
7		3	0	7	10.8			
11	17	2	31	+6	48.0	0.4541	0.3645	0.023

Gore's Stellar Heavens.—A careful reader of Mr. Gore's recent book, titled "The Stellar Heavens" has this to say about it: "In the chapter on Variables, it appears to me that the author has not exercised very critical care in the

selection and compilation of his material. In the list of interesting stars, he has omitted the most interesting and easily observed of Miller and Kempf's stars, SU Cygni, while he has inserted U Vulpeculæ, which is very difficult of observation, being too faint for the field-glass, and very inconvenient for the telescope."

"Among his Algol-type stars he mentions 'Serpentis,' which has for several years been officially known as RX Herculis, and which the writer found, two years ago, to have a secondary minimum, and to be more like β Lyræ than Algol in the character of its variation."

"As to the list of Suspected Stars, I fear I have little inclination to examine any of them. I have dealt with many of Mr. Gore's suspected variables and can remember confirming only one, X Herculis. I have found several interesting cases of the effect of position angle among them, for one of which see A. J. XIV, 14."

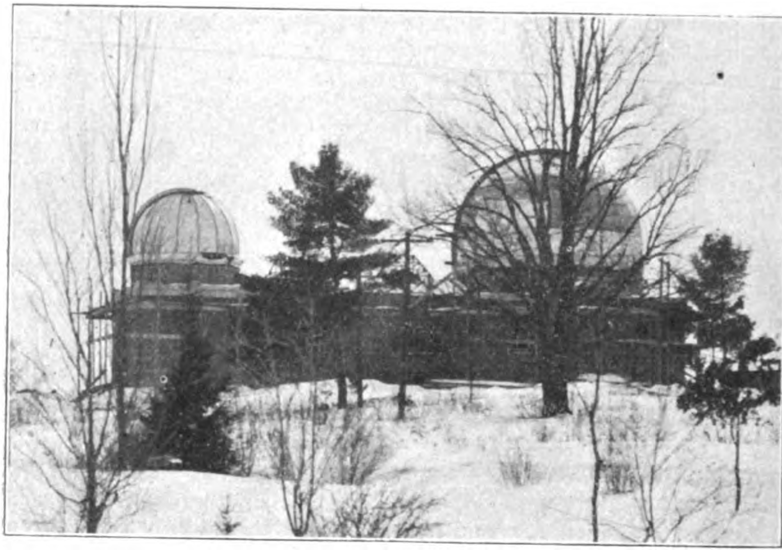
"It seems perhaps a little ungracious to call attention to these points, but in view of Mr. Gore's position among the English amateur astronomers, we have a right to expect more careful preparation of the matter he sends out. It is a little singular that both Mr. Gore in his book, and Col. Markwick, in the paper recently reprinted in your pages, pass so lightly over the effect of position on the estimates of the relative brightness of two stars. Gore passes the subject by with a quotation from Pickering (p. 83) without a word as to the importance of the matter, and Markwick (P. A. XII, 198) with a simple definition of it, and this with respect to a source of error whose influence I am still in fear of after many years of practice, and which I take ever increasing precautions to eliminate from my observations."

We have such full confidence in our correspondent's accurate knowledge of the points made in the above criticism that we welcome them to our pages, and thank him for making them so freely, especially in regard to the things we had not noticed and which refer to the matter of our own publication. We also believe that Mr. Gore will heartily welcome the friendly criticism herein made in regard to a few points in his latest book.

Director Campbell receives the Lalande Prize.—The French authorities, who have large sums available for such purposes, have pursued a most generous policy in making the awards for scientific discoveries and explorations not along national lines. Director W. W. Campbell, of Lick Observatory, has just been awarded the Lalande prize by the Paris Academy of Sciences for the most important work in astronomy.

For 1904, they offer in addition to the Lalande prize, the Laconte prize ($10,000) for a capital discovery in mathematics, physics, chemistry, natural history or medicine; and the Wilde prize ($800) for a discovery in astronomy, physics, mineralogy, geology or experimental mechanics.

New Observatory at Amherst College.—The cuts of the new Observatory herewith given show that the progress in construction is moving towards completion. The feature of having the Director's house, near by, and part of the outfit of an observatory plant is an excellent one. In this Professor Todd is to be especially congratulated. Full description of the working parts of the Observatory will be given later.



New Observatory at Amherst College.

Director's House.

Miss Sarah F. Whiting, for many years Professor of Physics and Physical Astronomy in Wellesley College, has just been made Director of the Whitin Observatory there, the administration of the affairs of the observatory being added to her duties as professor. Miss Ellen Hayes, Professor of Applied Mathematics in the same college, has been made Professor of Astronomy and Applied Mathematics. She is associated with Professor Whiting in the practical work carried on in the observatory.

The Spectroscope for Small Telescopes.

THE EDITORS OF POPULAR ASTRONOMY:

May I add a note to the description of a spectroscope for small telescopes in your April issue?

I have a somewhat similar instrument made by Mr. Brashear which I purchased from an advertlser in your journal. I however have made the following alterations to it which considerably add to the comfort and pleasure of using it for solar prominence observation. First with a plain eyepiece in the collimator such an instrument brings the head of the observer into most uncomfortable positions when observing certain parts of the Sun with a tangential slit. The first alteration I had made was to insert a total reflection prism to the sliding part of the collimator tube with an adapter to take the eyepiece. In my case this necessitated the substitution of a somewhat longer focussed object glass for that originally in the telescope of the spectroscope. Next for the straight slit I had substituted a curved slit the radius of which corresponds to the maximum size of the Sun's image of my 3-inch refractor. The arc of this curve is about 120°. With four or five settings I can conveniently survey the whole circumference of the Sun. Another addition which however is somewhat more serious is the application to the main telescope tube of one of Thorp's rotators by means of which the entire solar image can be rotated on its axis by the action of a tangent screw. The eye and eyepiece remain stationary and it is really curious to thus see the Sun turning like a wheel on its own hub. I do not think the advantage of this apparatus (for small telescopes only) is sufficiently appreciated by prominence observers.

An incidental advantage of the diagonal prism at the eyepiece is that the right and left hand reversal (by the reflection from the grating) is corrected and a prominence is seen as though observing with a direct vision spectroscope. The sketching of prominences with due reference to proper orientation is thereby facilitated.

Yours truly,

E. T. WHITELOW, F. R. A. S.

70 Deansgate, Manchester, England,
April 19, '04.

New Bruce Telescope at Yerkes Observatory.—Yerkes Observatory has received its new Bruce telescope and our readers will be interested in a brief description of the instrument which came to us from one of the observatory staff: "It is a splendid piece of work—as all of Warner and Swasey's is. It is a triple mounted tube, a 10-inch doublet, 50 inches focus, by Brashear. A 6¼-inch Voightlander doublet of 31 inches focus, and a 5-inch guiding telescope, object glass by Brashear.

The mounting is somewhat similar to that of the Potsdam telescope, but a great improvement on that mounting. The pier is bent to form the polar axis,

so that the system of the telescope can swing free when crossing the meridian in any declination, so that a continuous exposure can be made from horizon to horizon in any part of the sky.

The telescope is placed in a small but handsome observatory made especially for it."

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Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

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Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. Appropriate blanks have been prepared and will be sent out generally to secure this important information. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

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All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U S A.

PLATE XI.

E

W

THE EXTERIOR NEBULOSITY IN THE REGION OF THE PLEIADES.

From a Photograph taken with the 6 inch Brashear Camera of Goodsell Observatory Nov. 7-8, 1899.
Total exposure 7 hours.

Popular Astronomy.

Vol. XII No. 6. JUNE AND JULY, 1904. Whole No. 116.

THE "CANALS" OF MARS.

W. W. PAYNE.

We have been much interested of late in the lively discussion that has been going on in scientific publications about the so-called "Canals" of Mars. We have given place to a considerable number of papers presenting the observations of many astronomers since the favorable opposition of Mars in 1877. These have included observations of Schiaparelli, W. H. Pickering, Percival Lowell, E. E. Barnard, Mr. Denning and those of many other astronomers of some experience in planet work.

The thing that is most prominent in the mass of writing that has appeared during the last twenty years is the very general agreement of the maps of the surface of Mars that have been made by so many careful and competent observers. This fact means much for the real advance of astronomy in a field beset with difficulties. Such observation can not be made with any but the best of telescopes. Such work can not be done, to any extent, where or when the atmosphere is unsteady, murky or dust-laden, and such details for map-making can not be proved by any power different from, or less than, the well trained human eye.

When an astronomer makes a study of these maps of the surface of Mars, he feels pretty sure of one thing, that he has a picture before him of what competent and faithful observers have really seen; for he knows that so many witnesses could not be mistaken in seeing the same details in almost endless variety, unless they had a real existence. The scrutiny of these details of the surface markings of the planet has been so sharp and so often repeated that the specialists in the study of Mars know if changes in them take place. They know what they ought to see at a given time and in a given phase of the planet, and if some of the minute details of the minor markings do not appear as they

should, at a predicted time, such facts are noted with especial care, as matter for further critical observation. In this way a great many observations of the detailed study of the planet have been accumulating in recent years, of which no one can speak particularly and safely who has not been patiently through this kind of work, and has come into that stage of its knowledge which is possessed only by the trained observer. Much less will he be able to dispute what an able observer shall say about the correctness of observations or the accuracy of maps constructed from such observations.

In reading the work of the great astronomers of the world one is impressed with the fact that those noted men seemed to get things, in some, measure, by a kind of astronomical intuition, just as a good reader of any language will get the meaning of a strange word by the connection and the sense it should bear in the place where it stands. In somewhat the same way we must give credit to trained observing for a kind of knowledge which others can not possibly possess by other means, or get from other sources.

In the second place when the astronomer comes to the point of making a map of the surface of the planet Mars, he will use his own observations, diligently compare them with the work of many other trustworthy observers and then commit his results, thus verified, to paper, as a map for reference bearing a given date. This is distinctly the work of observational astronomy in the line of the surface study of a planet by the aid of the visual telescope. In this, photography is of no use, nor will the spectroscope aid him in the least. He must here depend wholly on the principles of the old astronomy, so-called, for all the data which he is to work into the details of a surface map. It is the visual telescope, the micrometer and the trained eye that are the essentials in this fascinating field of investigation. The maps of the surface of the planet Mars màde by Schiaparelli, Lowell, Pickering, Flammarion and many others are pieces of astronomical work that are now classical in astronomy, and they are likely long to remain so, because they were made by the very best means and methods now known to that science.

So far we can speak of the "canals" of Mars quite securely and satisfactorily; but when we go much further, and begin to draw inferences from observations and the maps that astronomers have made, we at once enter a field of conjecture and uncertainty. This is really the third stage of astronomical study, or that of any branch of science, through which the investigator must go

to determine a law of nature. It is the theoretical stage of knowledge; it is a condition precedent to law and fact and it is just as necessary, as any other in the logical train which leads to new truth and new knowledge in any direction.

The great trouble that is apt to arise in the discussion of new data in astronomy is the fact that the disputants too often lose their patience, and sometimes their good sense, in their treatment of the honest views of opponents. Truth always suffers in such dealing. But,

"Truth crushed to Earth will rise again," and those who suffer most are those who fail to be candid and perfectly just in the treatment of opposing opinions.

Let this discussion go on, fairly and fully, not foolishly, scornfully or needlessly prolix but honestly, thoroughly and to the finish, if there is data enough to carry it to so wide and so satisfying induction. But, we think it ought to be remembered always that all theories evolved from earnest and successful discussion, must stand the crucial tests of appropriate observation some time, before they can be accepted as anything more than working theories in the progress of establishing that which is new.

In the matter we are now speaking of, we have been much interested in what appears in the May number of *Knowledge*, 1904, page 87, in an article having the same title as we have chosen. Mr. Maunder, the writer of that article has treated the views of his opponents so fairly and so conscientiously that we wish to adopt it entirely, and have given it below in full with the illustrations.

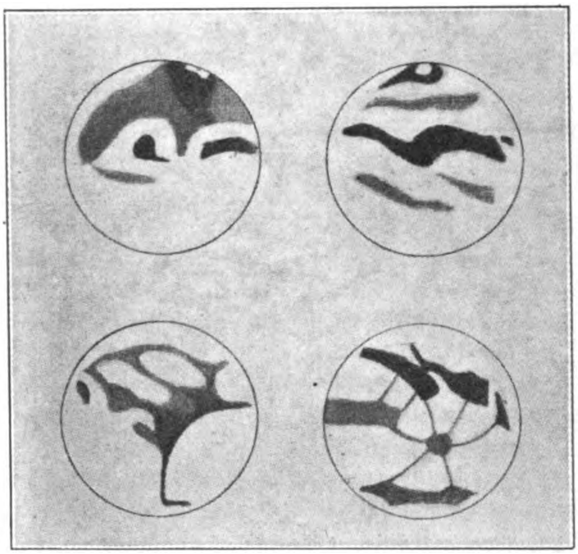
"Several correspondents having expressed a strong wish that I should give some reply to Mr. Story's letter on this subject, I will endeavor to do so; not without reluctance, as the line which Mr. Story took seemed, in my opinion, hardly likely to advance our knowledge."

"If I may briefly summarize Mr. Story's objections to the paper communicated by Mr. Evans and myself to the Royal Astronomical Society last June, they come under three heads. He objects to me as the author, to the methods employed, and to the deductions drawn."

"The first objection is of course a somewhat delicate one for me to handle. It deals rather with the personal than with the scientific, and I have no inclination to fill the columns of Knowledge with detailed evidence of my claim to be considered an "expert" on the subject of Mars. Let it suffice that as long ago as 1877,

I had made a thorough study of the planet, using the fine 12¾-inch Merz refractor of Greenwich Observatory. In 1892 and 1894 I also used the 28-inch Grubb refractor—certainly one of the most perfect objectives in existence. I give two or three ex-

1. 2.



3. 4.

FIG. 1.—DRAWINGS OF MARS MADE THE 12¾-INCH REFRACTOR OF THE ROYAL OBSERVATORY, GREENWICH.

	h	m		h	m
1. 1877 Sepeember 29th	10	10	2. 1877 September 24th	11	43
3. 1879 November 5th	13	5	4. 1882 January 9th	12	2

amples of my earlier drawings, from which it will be seen that I had recorded some of the markings now familiar to us as "canals" and "oases," even before Schiaparelli had published his results, and quite a number before they had been generally recognized by observers."

"So much for the person, next for the methods. Mr. Lowell and Mr. Story both appear to object to the employment of terrestrial experiments to elucidate planetary appearances. Mr. Lowell's opinion to this effect may be found in his letter published in the "Observatory" for January, 1904, p. 49: "Permit me, in conclusion, to point out to you * * * that the only evidence germane to the matter is to be got from astronomical observations directed to that end." But as Mr. Story points out, Mr. Lowell himself has set on foot terrestrial experiments for the express purpose of drawing inferences with respect to his observations of Mars, and Mr. Story approves of his so doing. Eliminating what is common to the two cases, the one of which meets with

Mr. Story's approval, and the other with his disapproval, the only residuals are Mr. Lowell on the one hand and myself on the other, and the statement is reduced to the simple proposition that he approves of Mr. Lowell and disapproves of me, irrespective of our actions. In other words, his second objection is but a more diffuse way of restating his first."

"But to take the matter seriously, let us see precisely what is the point where Mr. Lowell's views and my own diverge. It is not in the chief markings of Mars. Mr. Lowell sees and draws these substantially as I saw and drew them in 1877, and as Beer and Mädler drew them in 1830. It is not in respect to the appearance of the "canals;" I observed and drew "canals" as far back as 1877, and though of course Mr. Lowell has seen and drawn far more "canals" than I have, those that I saw were substantially of the same character as his; and in the discussion of this question I have been most careful, both in writing and speaking, always to point out that I was not throwing doubt either on the fidelity or the skill of any of the observers of Mars. Mr. Evans and myself wrote: "It would not be in the least correct to say that the numerous observers who have drawn 'canals' on Mars during the last twenty-five years, have drawn what they did not see. On the contrary, they have drawn, and drawn truthfully, that which they saw." ("Monthly Notices, Vol. LXIII., p. 499). Nor have I ever asserted or assumed "that the canals are seen as very faint lines, so faint that their existence is doubtful even to experienced observers." I know the reverse by actual experience."

"We agree on a third point. Mr. Lowell is absolutely convinced, and in this I am quite at one with him, that it is not possible that an actual network so geometrical as that which he represents can be the result of purely physical causes. Mr. Story has no doubt seen the very fascinating book which Mr. Lowell published on "Mars" in November, 1895, and has read the pages 148-154."

"After this we differ. Mr. Lowell attributes this confessedly utterly unnatural network to the handiwork of intelligent beings who have woven over their planet these "grotesque polygons" to use Schiaparelli's expression."

"This, be it noted, is inference, not observation; and an inference which demands the assumption that, were Mars brought much nearer to us, or our power of seeing greatly improved, these grotesque polygons would still persist, and would never resolve themselves under better seeing into markings which we could

reasonably ascribe to the unaided processes of Nature."

"My inference is different; the unnaturalness may be due to the imperfection of our seeing. I rely on well-known facts respecting the theory of vision and the structure of the eye, and the eye is our necessary instrument for observation. We have no right to resort to the unknown and the artificial, before we have exhausted the known and natural methods of explaining a phenomenon. My inference is one based on the observed effects of known causes; Mr. Lowell's inference is an excursion into fairyland."

"We know that the smallest single dark marking on a bright ground which can be seen by an observer of perfect sight, without optical assistance, must have a diameter of at least 34 seconds of arc. This diameter depends upon the size of the rods and cones of the eye which receive the visual impression, and compose the sensitive screen. It is therefore an inevitable limit. As this diameter is necessary for the object to be merely perceived, or, in other words, to create any sensation at all, it follows that in order that the actual shape of the object may be recognized, its diameter must considerably exceed this limit, otherwise it will be seen as a truly circular dot, whatever its actual shape."

"This is the case for small isolated markings just within the limit of visibility: The case is different for extremely elongated markings; the increased length of a marking will compensate for diminished breadth up to a certain limit, but not beyond it. For a line of indefinite length the limit of breadth approaches two seconds of arc. A line of a breadth below one second of arc is invisible, no matter what its length; but it must have a breadth many times this amount before it can be seen as anything else than a mere line—before irregularities in shape and breadth can make themselves apparent."

"In naked-eye vision, therefore, there is a considerable range within which small objects, whatever their true shape or nature, can only be seen as dots or as lines. The result is that these two forms are certain to come in evidence whenever we are dealing with objects too minute to be fully and properly defined."

"The problem becomes more complicated when we are using optical assistance, as there is a limit of definition belonging to the telescope as well as to the eye. But the principle remains the same; the result of adding the limitation of the telescope to the limitation of the eye being that the actual magnification of the telescope can never be nearly as effective as it is nominally. A power of 300 on the best telescope in existence, and under the

best atmospheric conditions, would never show the features of the Moon as distinctly as they would be seen if the Moon were brought 300 times as near."

"Mr. Story and Mr. Lowell both object that terrestrial (or, as they are more usually called, "laboratory") experiments are altogether beside the mark when applied to the interpretation of astronomical observations. The contention is a ridiculous one, and if logically applied would render it impossible to determine the instrumental errors of a transit circle by the use of meridian marks, collimators, or mercury trough, or the personal equation of an observer, except by actual stellar observation. They would also forbid us to identify the lines of solar or stellar spectra by comparison with those of any terrestrial element."

"But since it is contended that Mars alone can give us valid information on the subject, to Mars let us refer. If we turn to the drawings made by Beer and Mädler in 1830, two small objects exceedingly like one another appear repeatedly. These are two dark circular spots, the one isolated, the other at the end of a gently curved line. Both recall the "oases" which figure so largely in many of Mr. Lowell's drawings, and the curved line at the termination of which one of the spots appears, is not un-

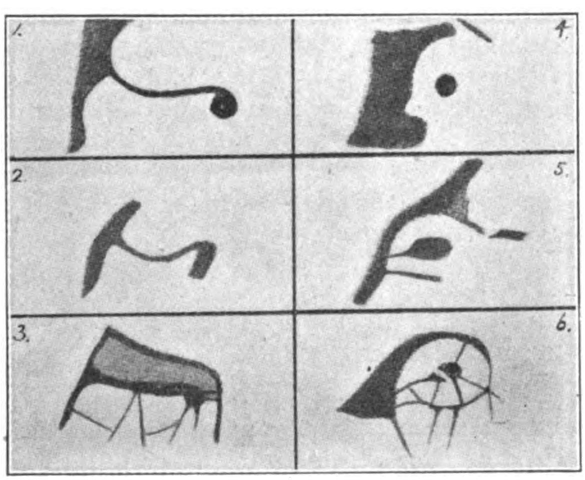


FIG. 2.—SINUS SABÆUS AND LACUS SOLIS.

1. Sinus Sabæus. . . .	Beer and Madler	1830.
2. " "	Lockyer . .	1862.
3. " "	Schiaparelli. .	1890.
4. Lacus Solis	Beer and Madler	1830.
5. " "	Lockyer . .	1862.
6. " "	Schiaparelli. .	1890.

like the representation which has been given of several of the "canals." There can be no doubt that in the year 1830 no bet-

ter drawings of Mars had appeared than those to which I have referred, and that in representing these two spots as truly circular Beer and Mädler portrayed the planet as they best saw it. The one marking we call today the *Lacus Solis*, the other the *Sinus Sabæus*, and we can trace the gradual growth of our knowledge of both markings from 1830 up to the present time. The accompanying sketches of the same region by Lockyer, in 1862, and by Schiaparelli, in 1890, illustrate well how the character of the markings revealed themselves with increased telescopic power and experience in the observer.

"At first it seemed a little speck
And then it seemed a mist,
It moved and moved and took at last
A certain shape I wist.
A speck, a mist, a shape."

If Beer and Mädler, in 1830, had argued that the precise circularity of these two spots, as they appeared to them, was proof that they were artificial in origin, would they have been correct? Would not the answer have been valid that a spot too small to be defined must appear circular, and that, therefore, the apparent circularity probably covered detail of an altogether different form? We know that it would. Yet it is that same argument in a far stronger form against which Mr. Lowell and Mr. Story are contending today. Beer and Mädler only drew two of these spots; Lowell shows over sixty. Beer and Mädler's two spots seemed to them precisely alike; how utterly different those two spots appear to us today the diagram may serve imperfectly to indicate. Mr. Lowell's sixty or more "oases," with one or two exceptions, appear all of the same character. Will any one dream that if the next seventy years brings telescopic development equal to that shown in the last seventy, the present uniformity of Lowell's "oases" will persist, any more than the likeness of the two spots observed by Beer and Mädler? We need not even wait for the seventy years. Up to the present moment I have carefully avoided anything like criticism of the drawings of any observer of Mars. I have repeatedly stated that I accepted them as being both faithful and skillful representations of what the observers saw. But it is necessary here to point out that the extreme simplicity of type of both "canals" and "oases," as shown by Mr. Lowell, is not confirmed by the best observers. In the last number of "Knowledge" Mr. Denning writes (p. 67): "There are really many distinctions in the canal-like markings; some of them are quite broad and diffused shadings, while others are narrow,

delicate lines." The Rev. T. E. Phillips has recently insisted strongly ("Monthly Notices," Vol. LXIV., p. 40) on the same fact, and I could increase the testimony indefinitely. There can be no doubt that the best observers not merely agree in stating that the "canals" differ very widely in their characteristics, but they also agree closely in the characteristics they assign to special "canals." With regard to Lowell's observations I can, of course, speak only with reference to those which he has published, but speaking with reference to these there can be no doubt that he fails to exhibit that wide variation in character between certain "canals" upon which these and other leading observers are fully agreed. This seems to me clear proof (so far as his published drawings go) not of superior conditions and skill on Mr. Lowell's part, but of a most marked inferiority in one respect or the other. Whether it be the location of his observatory that is at fault, or the definition of his telescope, or his own personal skill in observation, or most probable of all, in delineation, the fact remains that—despite the multiplicity of his observations and the perseverance, which cannot be too highly praised and too fully recognized, with which he has observed Mars in season and out of season—he has failed to record differences apparent to a consensus of other first-rate observers. Especially he has failed to recognize what Denning and Schiaparelli had recognized as early as 1884, that many of the "canals" were very far from being straight lines of uniform breadth and darkness, but showed evident gradations in tone, and irregularities occasioning breaks and condensations here and there. Of all the thousands of drawings of Mars which I have examined, those that most perfectly corresponded to Mr. Lowell's were the work of a young novice and were made in by no means an ideal station, using a small home-made telescope."

"It is made an argument in favor of the actuality of the "canals" that they have been seen with such distinctness, or with such frequency. The argument is based upon a very complete ignorance of the appearance of the fictitious "canals" observed in the experiments made by Mr. Evans and myself. I have myself been completely taken in by a little drawing on which the Syrtis Major and Sinus Sabæus were shown. As I looked at it by far the most insistent feature was a straight, narrow, intensely black line corresponding to the Phison. Yet that astonishingly vivid impression was really due to the integration of two or three feeble lines, irregular, broken, and serpentine curves, and half a dozen utterly invisible dots. If I had looked at that

drawing a thousand times, or if a thousand other observers had examined it under the same conditions as to distance, they could only have seen what I saw—a dark, straight line, as sharp as if cut by a graving tool."

"The change in the distinctness of the "canals," consequent on the progress of the Martian seasons, was no discovery of Lowell's; the fact was realized by Schiaparelli very early in his observations. But so far from rendering it more probable that the "canals" indicate artificial water-ways, it affords a most serious argument against their having that character. For water cannot flow uphill, yet the water from the melting polar snow, according to Lowell, must flow upwards to reach the equator. If, with Lowell, we consider the dark markings on Mars to be vegetation rather than water, they would change in appearance with the seasons whether they were of natural origin and irregular shape, or were artificial and symmetrical; and Mr. Lowell's 8500 observations do not increase the probability of his theory more than 85 or 8½ would do. A "canal" or an "oasis," if seen only as a straight line or a circular dot, that is to say, if seen only in the simplest possible form, affords no proof that the precise form under which it appears has any actuality. It is only when the object begins to show detail that we are sure that we are beginning to see it as it is. And one of the most convincing testimonies that Mr. Evans and myself have been following the right line has been shown by the attitude which the most experienced observers of Mars have adopted towards our inquiry. They have claimed, as Mr. Denning did in last month's "Knowledge," that certain "canals" are undoubtedly real, for they have been resolved or partially resolved into minuter details, being "composed of small, irregular condensations." Others they have admitted may be "canals" only in appearance, being actually either "the edges of half-tone districts or the summation of very minute details." In both the claim and the admission they are in perfect accord with the position held by Mr. Evans and myself. On the other hand, Antoniadi, Barnard, Denning, Molesworth, Stanley Williams, have all held themselves aloof from the bizarre delineations and yet more bizarre theories which Lowell has promulgated. Most striking of all, Mr. W. H. Pickering, who preceded Mr. Lowell in his argument that the water supply in Mars is restricted, and in the recognition of the system of "oases," who further has had the opportunity of observing with Mr. Lowell's telescope and in the climate of Arizona, has not only frankly accepted our position, but has supported it by direct

photographic proof. Mars, unfortunately, does not lend itself to photography, but the Moon does; and Mr. Pickering has found confirmation of our experiments as to the building up of straight-line systems from imperfectly seen details by comparing his drawings of certain lunar formations with actual photographs."

JESUIT ASTRONOMY.

WM. F. RIGGE, S. J.

PART II. CONCLUDED.

Observations.

The observations made by Jesuits during the 19th century are practically all the product of their four greater observatories of Rome, Stonyhurst, Kalocsa and Georgetown, in which alone some extended technical work has been possible, since all the rest either are of too recent a date or were built only for purposes of education. Even at these four observatories the work has been intermittent, principally on account of the pressure of other duties and the want of means, since they all are (or were) private observatories entirely dependent upon the charity of individual benefactors.

The Sun.

It is well within the bounds of moderation to assert that no work of any merit has been written on the Sun during the last thirty years without bringing in the name of Father Secchi. Born June 29, 1818, Fr. Angelo Secchi entered the Society of Jesus November 3, 1833. In 1849 he took charge of the Roman College Observatory, and rapidly became one of the foremost astronomers of his time. His work on the Sun is well summed up in his book Le Soleil, which will ever remain a classic in astronomical literature. He was one of the first to use the spectroscope upon the heavenly bodies, and he was by its means able to formulate a theory concerning the nature of sun-spots, prominences, faculæ, the corona and the whole Sun which has received the highest commendation and is quoted extensively in the writings of the best authors. To recount in detail Fr. Secchi's work on the Sun would be practically to give the whole theory as presented in our astronomical text books, a proceeding which would be as lengthy as it is unnecessary.

Fr. Perry, of Stonyhurst College, England, was another great student of the Sun. Born August 26, 1833 in London, he be-

came a Jesuit November 14, 1853. He had charge of the observatory from 1860 to 1862 and again from 1868 until his death in 1889. Besides the eminent work he did in meteorology and magnetism, such as the magnetic surveys of France in 1868 and 1869 and of Belgium in 1871, the routine work he inaugurated in Stonyhurst included the daily drawing of the Sun when possible, the measurement of the depth of the chromosphere, the observation of the heights, positions and directions of the prominences, and the recording of the spectra of sun-spots,—a long program that he most faithfully and consistently adhered to during the last ten years of his life. "With regard to faculæ, Fr. Perry established the fact that they do not precede the birth of a spot, but are most numerous and wide-spread when it disappears. Again, he has stated with regard to the distribution of faculæ, that it is much more general than that of the spots, many being visible even near the Sun's poles. Nor would it appear that the view that faculæ lag behind a sun-spot receives any confirmation from the Stonyhurst drawings."* The "veiled spots," independently discovered at Stonyhurst, have been watched with persistent patience for several years. The mean depth of the chromosphere was found to be about 4000 miles.

But Fr. Perry probably came most prominently before the notice of the scientific world on account of his many important astronomical expeditions, "in fact, it has been stated by those who ought to know best, that he was a member of more scientific expeditions than any living astronomer.† On December 22, 1870, he observed a total eclipse of the Sun at Cadiz in Spain. Filmy clouds prevented the complete success of his work. In 1874 he was appointed by the astronomer royal to command the expedition to Kerguelen or Desolation Island in the South Indian Ocean in order to observe the transit of Venus on December 8 of that year. As the longitude of the place was to be determined with the utmost care, the program included 100 double observations of lunar altitudes or azimuths and 30 transits over the meridian, and it took a weary exile of five months to execute it. In 1882 Fr. Perry was again selected to lead another expedition to observe the second transit of Venus of the century, that of December 6, at Nos Vey, Madagascar. August 29, 1886, he observed a total solar eclipse at Carriacou in the West Indies. For the eclipse of August 19, 1887, he went to Russia, but the expe-

* The Scientific Work of Father Perry, by Fr. A. Cortie, in The Month, for April 1890.

† Ibidem.

dition was a complete failure on account of the clouds. On December 22, 1889, he observed a total eclipse at Salut, near Cayenne, in the West Indies, where he died of a pestilential fever five days later. Fr. Perry's photographs of the solar corona and spectroscopic work during the eclipses did much to advance the cause of science.

Fr. Fényi of the Haynald Observatory, Kalocsa, Hungary, has very faithfully carried on the program of solar work he proposed to himself in 1885, and the numerous and periodical publications of his observatory testify to his ability and his perseverance. He has observed the solar prominences with special care, and has systematically mapped them upon the Sun's limb. The more remarkable protuberances he has observed in detail, and as far as possible, noted the changes they undergo. Some of the results of his long series of observations have a bearing on the recent investigations of the interrelations of magnetic disturbances on the Earth and solar phenomena. He states* that he finds that the eruptions of the greatest prominences, except when they are metallic ones near large spots, never coincide with magnetic disturbances. Faculæ and spots have not the close relation to protuberances that is generally taken for granted. And those faculæ which appear outside of the active spot zone, are only sometimes and quite accidentally accompanied by prominences. The structure of the prominences, before they are torn to shreds, is almost always one consisting of stripes, bands or threads.

In a short summary† of his solar work he says that the greatest heights attained by the protuberances during the different years coincide remarkably with the period of sun-spot activity, the maximum of only 165″ in January 1887 falling very close to the minimum, and the enormous maximum of 690″ in September 1893 close to the maximum of the spot period. The heliographic latitude of these maximum prominences seems to follow no law, except that it never exceeds 41°.

The Planets.

In regard to the planets we again find everywhere the name of Fr. Secchi. Thus he was one of the first to see the so-called canals on Mars,‡ to observe Jupiter's third satellite as spotted,¶ etc. I also pass over Fr. Perry's observations of occultations

* Publications of the Haynald Observatory, No. 8, 1902.

† V. J. S. 33, pp. 315-318.

‡ Clerke's Hist. of Astron. p. 327.

¶ Idem, p. 339.

and of Jupiter's satellites.* The most prominent work on the planets was probably Fr. De Vico's determination of the rotation period of Venus and the inclination of its axis, which was considered so exhaustive that it was not questioned for half a century; and even today the controversy between De Vico's 24-hour and Schiaparelli's 225-day periods cannot be said to be closed.† Fr. De Vico also measured the eccentric position of Saturn in his rings and observed the motions of Mimas and Enceladus, the two inner moons, which had not been seen except by Herschel. Arago‡ praises him for the invention of an instrumental device that enabled these satellites to be seen in telescopes much smaller than the one used by Herschel.

The Stars.

In regard to work on the stars, we may again point to the indefatigable Father Secchi. Clerke says:¶ "The effective founders of stellar spectroscopy * * * were Father Secchi, the eminent Jesuit astronomer of the Collegio Romano, where he died, February 26, 1878, and Dr. Huggins, with whom the late Professor W. A. Miller was associated. The work of each was happily directed so as to supplement that of the other. With less perfect appliances, the Roman astronomer sought to render his extensive rather than precise; at Upper Tulse Hill, searching accuracy over a narrower range was aimed at and attained. To Father Secchi is due the merit of having executed the first spectroscopic survey of the heavens. Above 4000 stars were in all passed in review by him, and classified according to the varying qualities of their light. His provisional establishment (1863-67) of four types of stellar spectra has proved a genuine aid to knowledge through the facilities afforded by it for the arrangement and comparison of rapidly accumulating facts. Moreover, it is scarcely doubtful that these spectral distinctions correspond to differences in physical condition of a marked kind."

Fr. Secchi also made innumerable observations of double stars, as works upon that subject will show.

Father Hagen, of the Georgetown College Observatory, though not a founder of a branch of astronomy as was Fr. Secchi, has

* Monthly Notices R. A. S. vols. 33, 34, 38-49.

† POPULAR ASTRONOMY, No. 75, p. 290, and No. 109, p 518. Astronomische Nachrichten Nos. 3641, 3891, 3892.

‡ Bibliotheque de la Comp. de Jésus, vol. 8, p. 645, which refers to Comptes Rendues of Oct. 10, 1842, pp. 747, 750, 751.

¶ History of Astronomy during the Nineteenth Century, second edition, New York, 1897.

rendered such great service to the branch of variable star observation as to put it on a new footing. His Atlas Stellarum Variabilium has filled a long-felt want and has supplied observers with essential and reliable data with which to carry on their observations. The Atlas, which began to appear in 1899, consists of about 250 charts divided into 5 series. There is one chart for each variable star, except when two or more are very close. This star occupies the center of the chart, and an enclosing square of half a degree gives all the stars down to the 13th magnitude, which may be used for identification and comparison. The magnitudes and positions of these comparison stars are plotted on the chart and are also catalogued with great care and exactitude. The rest of another circumscribing square of one whole degree contains stars copied from the Bonn Durchmusterung.—Fr. Hagen's prompt construction of a chart for Nova Persei in March 1900, helped very materially towards obtaining and discussing valuable observations of this wonderful star.

Fr. Sidgreaves, Director of the Stonyhurst College Observatory from 1862 to 1868, and again from 1890 until the present, and companion to Fr. Perry in his transit of Venus expeditions and magnetic surveys, is continuing Fr. Perry's meteorological, magnetic and astronomical work and devoting himself in addition to stellar spectroscopy. "His most important investigation is fully described in his well-known Memoir (published by the Royal Astronomical Society) on the spectrum of Nova Aurigæ. * * * The novelty of the arrangement is in the absence of a slit, the star being made to drift slowly in a direction parallel to the refracting edges of the prisms. The resulting spectra are surprisingly sharp, and the exposure is much less than that required with a slit spectroscope of the same dispersion."* Fr. Sidgreaves's photographs of the spectrum of Nova Persei, 1901, and of the changing spectrum of β Lyræ, of Mira Ceti, and many other stars, have been exhibited at the Royal Society, Royal Photographic Society and the Paris Exhibition, and elicited universal praise.

In regard to comets, Father De Vico discovered eight, one of them being the well known periodic one (5½ years) which bears his name.

Maps of Countries.

While endeaving to christianize the heathen in foreign countries, the Jesuits of today are treading in the footsteps of their

* Professor G. E. Hale, in Astronomy and Astrophysics, No. 121, page 58.

predecessors and making themselves useful to science. Thus, the Jesuits at Zi-ka-wei "have issued numerous excellent maps either separately or as appendices to other works. The first of these classes is represented by a "Map of China at the Time of Tsch'oen = ts'ieou" (Chronicle of Confucius 722-481 B. C.) drawn by Fathers J. Lorando and J. B. P'e, the old names being in red and the modern ones in black. Then there is the "General Map of China," 1894, (100 x 73 centimeters) of Fr. S. Chevalier, which gives all the prefectures and sub-prefectures. Concerning the maps accompanying Fr. Havret's "The Island of Tsong-ming" in the first number of the periodical called Variétés sinologiques published at Zi-ka-wei, ex-cônsul H. E. Parker (an English Protestant) says: "There are two very excellent maps; one gives a picture of the whole province and is of altogether inestimable value to travelers; the other is a complete map of those parts of the Yang-tse-Kiang which flow through Ngan-Hoei." "*

"The Logerot Gold Medal of the Paris Geographical Society has been conferred upon Father Chevalier, of the Kiang-nan mission. The President of the Society in bestowing it said: "Father Stanislaus Chevalier arrived in China in 1883, and since then has devoted his learning and energy to the development of the Zi-ka-wei Observatory, near Shanghai. His remarkable studies on the typhoons of the China Seas long ago attracted the attention of the scientific world, and now the publication of his Atlas of the Upper Yang-tse appears to this Society an excellent opportunity of rewarding this modest scholar who, to the honor of France, is accomplishing this immense work in the province of Kiang-nan. The result of his long and fruitful journey through Sze-chuen allowed Father Chevalier to accomplish, between November, 1897, and March, 1898, the surveys necessary for his Atlas of the Upper Yang-tse, from I-chang-fu to Ping-shan-hien. This Atlas, consisting of two parts, containing the journey and a description, is composed of 64 plates, on the scale of 1 : 25000. We may judge of the magnitude of Father Chevalier's work when we know that, in order to compile the table of statistics astronomically fixed between I-chang-fu and Ping-shan-hien—not to speak of observations of meridional passages of stars, about 450 in number, and now of the observations between I-chang and Shanghai—he had to take over 800 altitude observations of the Sun and stars, each observation being separately calculated after a very

* Die Katholischen Missionen, Freiburg, Switzerland, Vol. 26, Sept. 1898, p. 277.

rigorous method. Thanks to the labor of Father Chevalier, we may now say that if the hydrography of the Lower Yang-tse (except that of Shanghai, due to Septime Viguier) is English, that of the upper basin is French." "*

"The Geographical Society of Paris has conferred upon Fathers Colin and Roblet, of the Society of Jesus, missionaries in Madagascar, [for their map of the country] the Herbert Fournet prize, the greatest at its disposal. It consists of a gold memorial medal and of the sum of 6000 francs. M. Alfred Grandidier, a member of the Society, and commissioned to report upon the matter, remarked on this occasion that "in the entire history of travels no second example of such a comprehensive and completed production as that of Fr. Roblet's could be found." This father carried on the topographical survey of Imerina from 1872 to 1884, all alone, and in a country the greater part of which was yet wild, under almost insuperable difficulties, and not seldom at the risk of his life. He measured 32000 square kilometers and climbed 3000 mountain heights. * * * To this enormous labor the triangulation of the Betsileo country must also be added. Fr. Colin became his assistant in 1888, and at his own initiative built in Tananarivo the first French observatory in the southern hemisphere. After testing and making sure of Fr. Roblet's results, he continued with him to the east coast the geodetic, astronomical and magnetic measurements begun in Imerina. At the call of the government both then came to Paris to complete their work. Fr. Roblet's map proved a reliable guide to the French expedition according to the testimony of Generals Duchêne and de Torcy."†

But the Atlas de Filipinas, which appeared in 1900, will probably appeal more to American readers. It comprises a series of 30 maps, which embrace about 1725 islands and 118542 square miles of measured and about 1000 of unmeasured area. An ethnographic map gives the habitat of 69 tribes, an orographic one the mountains, volcanoes and ocean depths, and another the frequency of earthquakes. Professor Henry S. Pritchett, the superintendent of the United States Coast and Geodetic Survey, remarks in his Introduction to the Atlas: "Shortly after the Philippine commissioners reached Manila it was learned that a series of maps, covering the more important islands of the archipelago, was being prepared at the Jesuit Observatory, under the super-

* Woodstock Letters, vol. 30, p. 307, November 1901.

† Die Katholischen Missionen, Freiburg, Switzerland, Vol. 27, Nov. 1898, p. 49.

vision of the director, Rev. José Algué, S. J. An inspection of such maps as had already been completed satisfied the commission that they were superior to anything hitherto published.* * * The commission conceived the idea of securing their co-operation in the preparation of a comprehensive atlas of the archipelago. * * * It is an interesting fact that the technical work was executed wholly by native Philippine draughtsmen. It was carried on under the immediate supervision of Rev. Jose Algue, S. J., Director of the Manila Observatory. The entire absence of accurate surveys of many of the islands was necessarily a serious drawback, but the Jesuits spared no pains in securing all available data, and verified them by consultation with members of the other religious orders, as well as with old residents, travelers and explorers. To the admirable work of their own Order is due practically all of our present knowledge of the interior of Mindanao."

We might also add in this connection that Fr. Secchi measured a base line in the States of the Church in 1858 and determined the length of a degree of the meridian. In 1867, as the representative of Pius IX he assisted at the Paris Conference which established the length of the meter.*

Published Works.

The Bibliothèque de la Compagnie de Jésus, new edition, in 9 volumes quarto, by Father Carlos Sommervogel, illustrates in the most convincing manner the literary activity of the Society of Jesus. But ours is the domain of astronomy only. I shall pass over the astronomical articles in popular magazines and newspapers and in technical journals, and the special publications of observatories, and shall call attention only to those works and those men that are specially eminent.

The ablest as well as the most prolific of modern Jesuit astronomical writers is beyond all doubt Father Angelo Secchi. In the Bibliothèque mentioned before the bare enumeration of the titles of his productions covers the amazing number of 19 pages quarto in double columns. In fact, his literary activity almost passes belief, and one hardly knows whether he can trust his eyes in scanning the long array of his productions, even in spite of the most exact references. He sent at least 643 communications to 14 journals.† The most important of Fr. Secchi's larger works are:

* Vox Urbis, March 1, 1903.

† Vox Urbis, March 1, 1903, but the Bibliotheque mentions 42 journals. Of these 643 papers, 133 appeared in the Astr. Nachr., 184 in Comptes Rendues, etc.

1. L'Unità delle Forze Fisiche, Rome, 1864. It has gone through two Italian, one German and one French editions.

2. Le Soleil, Paris, 1870. The second edition appeared in 1875. It has been translated into German and Spanish.

3. Le Stelle, Milan, 1877. It was translated into German and French.

4. A treatise on cosmography for the use of schools, and

5. Elements of Terrestrial Physics, both in Italian, the latter a posthumus publication, 1879.

Father Secchi was equally active in physics and in meteorology, and his large meteorograph, described in Ganot's Physics, merited for him the Grand Prize (100000 francs) and the Cross of the Legion of Honor at the Paris Universal Exposition of 1867. It was conferred upon him by the hand of the emperor Napoleon III, in presence of the emperors of Russia and Austria, and of the kings of Prussia and Belgium. The emperor of Brazil sent him a golden rose as a token of his appreciation.

The "Atlas Stellarum Variabilium" by Father Hagen, of Georgetown College Observatory is "the most important recent event in the variable star world."* "It will without doubt become in time an indispensable requisite of the library of every observatory, just as the Bonn maps have become."† Professor E. C. Pickering, of Harvard College Observatory, esteemed the Atlas so highly that he obtained from Miss Catherine Bruce, the great astronomical benefactress, a donation to the printer to enable him to undertake the work, and he is also endeavoring to secure the presentation of a 12-inch equatorial to Fr. Goetz of Bulawayo, (Rhodesia), South Africa, for the continuation of Fr. Hagen's charts to southern stars.‡ Fr. Hagen has also become a great factor in the mathematical world by his "Synopsis der Höheren Mathematik" in four volumes quarto.

Less well known perhaps, but not the less important in their own sphere are the books "Astronomisches aus Babylon" by Fathers Epping and Strassmaier, and "Die Babylonische Mondrechnung" by Fr. Kugler (Freiburg, 1900). "It is well known that the investigations made by the Jesuit Father Epping (in company with the Assyriologist Father Strassmaier) upon many Babylonian astronomical bricks have had as a consequence that

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* Popular Astronomy, No. 81, p. 50.

† Ernst Hartwig in V. J. S. vol. 35, p. 51.

‡ "A Plan for the Endowment of Astronomical Research," p. 12, (reviewed in Popular Astronomy No. 106 (Jun.-Jul. 1903) p. 352).

the scientific level upon which the history of astronomy had formerly placed the Babylonians, must be taken considerably higher. * * * Epping's investigations * * * now receive a very valuable extension through the labor of Father Kugler, of Valkenberg, Holland. * * * From our communication concerning the work of Father Kugler it may be inferred of what great importance his book is to the history of astronomy. Even if later discoveries made upon the Babylonian bricks should perhaps modify one or other view of the writer, the care and diligence with which he went to work stamp his book as indicating a very considerable advance upon Epping."*

"Die Gravitations-Constante, die Masse und mittlere Dichte der Erde nach einer neuen experimentellen Bestimmung," Vienna, 1896, by Fr. Carl Braun, of Mariaschein, Bohemia, represents about eight years of patient work and "bears internal evidence of great care and accuracy, and he obtained almost exactly the same result as Professor Boys.† Fr. Braun carried on his work far from the usual laboratory facilities, far from workshops, and he had to make much of his apparatus himself. His patience and persistence command our highest admiration."‡

"Ueber Kosmogonie vom Standpunkte christlicher Wissenschaft, nebst einer Theorie der Sonne und einigen darauf bezüglichen philosophischen Betrachtungen," by Fr. Carl Braun. "This problem, mighty in every respect," says Dr. Förster,¶ "is treated from almost all points of views with clearness and impressiveness. One could hardly at this time find in any other book all the essential features of a theory of the Sun collected together in such a directive manner." Fr. Braun is at present at work upon the third edition.

Conclusion.

To conclude. While I realize that I have not said all that was to be said upon the subject in hand, on account of not having access to all, nor even to the greater part, of modern astronomical literature, nor all the standard journals, I think I have said enough to convey to the reader a pretty fair idea of what the Society of Jesus has done in the field of astronomy. The cultivation of this field is only secondarily an object of the Order, and

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* F. K. Ginzel in V. J. S. vol. 35, pp. 256-273.

† That is, the Earth's mean density $= 5.52760 \pm 0.0013$.

‡ Recent Studies in Gravitation, Professor John H. Poynting, D. Sc., F. R. S., Proceedings of the Royal Institution of Great Britain, vol. XVI, part 2, Nov 1901, reprinted in Annual Report of the Smithsonian Institution, 1902, p. 203.

¶ V. J. S. Vol. 25, 1890, p. 56.

is the work rather of individual members or colleges than of the whole Society.

ERRATA IN PART I.

For Tyrnan read Tyrnau.
" Brensing read Breusing.
" 1653 and 1655 (Riccioli's Works) read 1651 and 1665.

CREIGHTON UNIVERSITY OBSERVATORY,
OMAHA, Nebr.

THE DOUBLE CANALS OF MARS.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY

A few years ago the doubling of the Martian canal system was generally admitted by astronomers as an accepted fact. Latterly however doubts have begun to arise with regard to it. It was shown by the writer, in the Harvard Annals XXXII, 149, that accepting the results of Schiaparelli, Flammarion, Antoniadi and Lowell, the double canals had this curious property, namely, that their linear separation was inversely proportional to the diameter of the object-glass of the telescope, and directly proportional to the distance of the planet.

It was then suggested that some one who was able to see the duplication of the canals, which the writer has never been able to do, should make measures of their separation, using different apertures in front of the telescope upon the same night. This has now been done by Professor Lowell, Bulletin No. 5, Lowell Observatory, and a recent examination of his work has shown that he has brought out some very instructive results.

In the first place as far as he is concerned it is evident that the separation of the canals is independent of the aperture of the telescope employed. Secondly, he has found that the duplication of the canals can be seen with surprisingly small apertures. Thus with six inches he divides the three double canals Euphrates, Hiddekel, and Gihon when their components were separated only $0''.27$, $0''.26$, and $0''.28$ respectively.

It was found by Dawes that an objective one inch in diameter could separate (not merely elongate) two equal stars $4''.56$ apart. A 6-inch objective should therefore separate stars at one-sixth this distance, or $0''.76$. Experiments made at Cambridge with a 15-inch aperture* showed that in order to divide two

* Harvard Annals XXXII, 149.

lines drawn in ink on white paper, they must be separated by an angle of 0″.42. For a 6-inch objective the required separation would therefore be 1″.05.

An analagous experiment may be readily repeated without instruments. Draw two lines in ink 1 millimeter, or one twenty-fifth of an inch apart, on white paper. Placed at a distance of ten feet they can just be divided with the naked eye. Their separation will be 70″. The diameter of the pupil of the eye in a brightly lighted room is about one-tenth of an inch. If we can conceive the pupil enlarged sixty times, which is what is practically done by a 6-inch telescope, we should be able to separate the lines at one-sixtieth of this distance apart, or at 1″.15.

Summarizing our results, and applying them to the case of a 6-inch telescope, we find from Dawes' experiments, confirmed universally by astronomers, that two stars could only be separated when as much as 0″.76 apart. The less the contrast the more difficult the separation. Therefore for black lines on white paper we need a greater separation than in the case of the stars. Our telescopic experiments with black lines indicate that the angle must measure 1″.05. Our naked eye experiments make the angle 1″.15. In the case of Mars, Professor Lowell can detect the duplication when the separation is only 0″.26. This would be equivalent in the case of the naked eye experiment to separating two lines one millimeter apart at a distance of forty feet. This the reader will find is quite impossible,

The writer hesitates to believe that Professor Lowell can separate two actual lines which are so much nearer together than the limit for other observers, and thinks therefore that what he sees must be some optical illusion.

REPORT ON THE REQUIREMENTS FOR THE MASTER'S DEGREE.*

At the Christmas meeting of the Chicago Section of the American Mathematical Society, held January 2 and 3, 1902, a committee was appointed to consider and report a scheme of requirements for candidates proceeding to their second degree, with mathematics as their major subject. It was thought that a mathematical program generally adopted in the central west would facilitate the migration of students from one institution to another, thus permitting students to take portions of their mathematical work at different institutions; that it would tend to preserve the value of the master's degree by making it represent equivalent attainments; and that it would enable the smaller colleges better to arrange their elective studies, so that students intending to make mathematics a specialty could, by a proper selection, obtain sufficient mathematical training to enter at once after graduation upon work which might be counted toward the master's degree.

This committee through its chairman sent a circular letter of inquiry to seventeen institutions of the central west, including all of the state universities from Ohio to Colorado, and others which may be regarded as of the same rank, or in which the mathematical department is especially strong. This letter invited a free discussion both as to the actual practice in these institutions and as to what might seem desirable as a mathematical program covering both the undergraduate work and that leading to the second degree. As a basis of undergraduate work it

* For some time there has been considerable discussion concerning the requirements that should be made, in mathematics, for entrance to college, for the Bachelor's degree and also for the Master's degree. The reason for this has been the lack of uniformity which it obtains in the best colleges East and West. In order to make it possible for students who wish for any reason to be transferred from one institution to another without uncertainty or hardship, a very strong sentiment in favor of uniformity of requirements is setting in this direction.

We call attention to this article more especially now because it will help to answer some of the questions that come to us frequently, asking what preparation is necessary in mathematics that students may later pursue the study of astronomy most advantageously.

This scheme of work which was presented to the Chicago Section of the American Mathematical Society and recommended for publication Jan. 1, 1904, covers this ground of preparation very thoroughly. We deem it an excellent guide for any student who wishes a thorough foundation in the mathematics for most of the branches in science which are carried forward to professional standards in the best scientific schools in the United States.—[Editor.]

was assumed that the student enters college with a thorough knowledge of algebra through quadratic equations and with plane and solid geometry. It was also assumed that the master's degree is to be conferred upon the successful completion of one year of *graduate* work, and that the college course covers four years of academic training. The scope of the inquiry is shown by the questions asked. They were as follows:

1. What should be the *minimum* acceptable time devoted to undergraduate mathematics?
2. What subjects should be included in the undergraduate course in pure mathematics? How much time should be devoted to each?
3. Should applied mathematics be required? What subjects, and how much?
4. Should French and German, one or both, be required? If only one, which one?
5. Should the candidate for the master's degree be required to pass a more rigorous examination than is required of the undergraduate?
6. Should a thesis be required?
7. Should the graduate work leading to the master's degree be confined to one, two, or three departments?

In order to make it more easily interpreted in the particular system of accrediting subjects at the several institutions, the committee has formulated its report in terms of recitation hours; thus a subject coming five times a week for one year of 36 weeks is assigned 180 hours.

After canvassing the replies from the institutions mentioned above, the committee submits the following mathematical program as giving the *minimum* preparations which should be accepted as sufficient for entering upon graduate work. It further reports a program of graduate work, which is recommended as the minimum basis for granting the second degree.

1. The minimum time devoted to mathematics in the undergraduate course should be 540 hours. This means that at least one-fourth of the student's undergraduate work should be devoted to the study of mathematics, if he expects to secure his master's degree in mathematics after one year of resident graduate study. Whether this amount, or more, be taken, it is recommended that it be distributed throughout the four years of the undergraduate course, to the end that the continuity of his mathematical study may not be disturbed as the student passes from his undergraduate to his graduate work.

2. The 540 hours mentioned above should be distributed substantially as follows:

I. College algebra, including the elements of determinants; trigonometry; and analytic geometry, including an introduction to solid analytic geometry. 180 hours.

II. Differential and integral calculus, differential equations, and mechanics. 225 hours.

III. Advanced algebra, including the general theory of equations; modern analytic and synthetic geometry, or solid analytic geometry. 135 hours.

3. The undergraduate instruction, especially in its earlier stages, should, by well chosen illustrations and applications, be kept in close contact with the physical sciences. Logical statement and proofs of theorems should always be delayed until their meaning is made familiar by application to special cases, and the problems considered for such purposes should be such as arise naturally out of concrete experiences. Whenever possible, a physical or a graphical solution of the problem should be given. In all mathematical teaching a clear comprehension of ideas and their correlation are of prime importance. In the earlier stages of any subject these can in general be best secured through the physical senses and by a method analogous to that of the general science laboratories. Abstract analysis should arise naturally in the effort to devise the most precise, clear, and convenient method of formulating and expressing the results of experiments and observations; and only in the later stages should it become an object of thought and investigation.

4. Upon the basis of the preparation indicated above, it is the opinion of the committee that the work leading to the master's degree should include at least 270 hours selected from the following groups of subjects. The selection should in any case include subjects from at least two of the three groups.

I. Geometry.

Projective geometry.
Modern analytic geometry, algebraic curves and surfaces.
Application of calculus to twisted curves and surfaces. (Differential geometry).
Solid analytic geometry.
Descriptive geometry (Darstellende Geometrie).

II. Analysis.

Theory of equations.
Advanced calculus.
Theory of functions.

Differential equations.
Theory of numbers.
Invariants.

III. Applied Mathematics.
Analytic mechanics.
Mathematical astronomy.
Mathematical physics.
Mathematical theory of probability.

This arrangement provides that the candidate, in case he enters upon his graduate work with the mininum mathematical preparation indicated above, and hence having a broader *general* training in his undergraduate course, should be required to take at least two-thirds of his year's graduate work in pure and applied mathematics. On the other hand, as it may be assumed that the student entering upon his graduate work with a larger mathematical credit than this has had less *general* training in his undergraduate course, it is the opinion of the committee that he should be permitted to take as much as one-half of his work in departments other than mathematical, providing, however, that the minimum requirement in mathematics indicated above is also fulfilled.

5. The candidate for a second degree should enter upon his graduate work with a sufficient knowledge of German to enable him to read easily mathematical works in that language. The committee thinks it very desirable that he should have also a reading knowledge of French.

6. It is the opinion of a large majority of the institutions with which the committee has corresponded, as well as the opinion of the committee, that in all cases a thesis should be required. This may not, and in most cases cannot, be in the strictest sense original research. It is, however, a convenient way of testing the student's ability to carry on independent investigation, and gives him an excellent preparation for research work later.

7. The examination of the candidate for a master's degree should be distinguished as to rigor and perhaps as to character from the ordinary term by term examination of the undergraduate student. Two plans are proposed, either of which, or a combination of the two, is commended.

(*a*) That the candidate be permitted to take the term by term examinations, as in the case of undergraduates, but that he should be expected to earn a higher grade than would entitle him to pass in case he were an undergraduate.

(*b*) That he be required to pass a final examination at the

time of taking his degree covering all of the subjects included in his graduate course.

The committee finds a great diversity of practice as to the amount of mathematics which is made the basis of graduate work at the various institutions mentioned at the beginning of this report. It believes, however, that the program outlined above is within the reach of all. Fnrthermorè, upon comparison with the requirements at several of the leading American universities, it was found that the minimum requirements which are here recommended are in substantial accord with the minimum requirements for the master's degree at these institutions.

It is the thought of the committee that, as meeting the above requirements in preparation for graduate work, the work of no institution claiming college grade should be accepted unless the major part of the work in preparation has been taken under the direction of mathematical instructors who have themselves done the equivalent of the work here outlined for the master's degree in mathematics.

By the adoption of the above mathematical program by the institutions represented in the Chicago Section, it is believed that a substantial service would be rendered the study of mathematics in the central west, not only by securing the advantage of uniformity in granting the second degree, but by elevating in some cases the standard upon which the degree is granted, and perhaps more than all else by giving to the small college, aiming to prepare for graduate work, a standard by which it may best arrange its elective system.

C. A. Waldo, Chairman,
E. J. Townsend,
Oskar Bolza,
Committee.

TIME.*

FOREST R. MOULTON.

Interrelations of the Sciences.

The evolution of the method of scientific inquiry has long been in the direction of specialization. The many new fields which have been opened up, as well as the remarkable advances which have been made in those which have longer been the subjects of investigation, have made these changes necessary. It has become practically impossible for a single individual to obtain such a general knowledge of different sciences which are not most in-

* Reprinted from *Journal of Geography.*

timately related, and at the same time such a command of necessary details and such expertness in technique that he can hope to make important contributions to them. This condition of affairs has developed a class of specialists whose achievements are justifying their methods.

There is, however, another sort of work, frequently of the highest importance, which consists in coördinating the results obtained in special fields. Indeed, as a general rule the importance of a fact is directly proportional to the number of its essential relations with other facts. Thus, the Newtonian law of gravitation and the law of the conservation of energy have played rôles of unparalleled importance in modern scientific discoveries because of their universal relations to physical phenomena. Therefore from a purely scientific point of view work in correlating facts may be of as much importance as any.

Likewise, in considering education from the utilitarian point of view, it is at once apparent that a knowledge of facts is of no greater importance than a just appreciation of their relationships. The ability to anticipate events, which is of so much importance in business and public life, consists to a very large extent in being able to draw conclusions from data which are available to all. Or, simpler still, ordinary common sense, which is one of the most valuable possessions one can have, doubtless consists largely in a just estimation of the relative importance of things.

It appears, therefore, that coördination is a valuable part of scientific work, and also that the average person should not only know facts but should thoroughly understand their relations as well. Everyone knows that the most valuable and lasting things he ever obtained from any teacher were not the few facts he may have been taught, but that they were the judicial attitude of mind and the intellectual balance which characterize good thinkers. It follows from these considerations that the average teacher, while being proficient in the subjects he teaches, should have a good knowledge of related subjects; that he should realize that the divisions of science are more or less artificial and for convenience; that, to obtain the best results in one subject, the points of contact with related subjects should be shown; and, above all, that the primary object is to develop the faculties of the student rather than to teach any subject. In accordance with these ideas this paper, as well as those which may follow, will be devoted to questions lying for the most part on the border lines between Astronomy on the one hand, and Geography and Geol-

ogy on the other, and an attempt will be made in them to show some of the relations existing among these sciences.

Time and its Measurement.

Formal definitions of what time is are frequently given, but they are usually mere combinations of words which mean nothing to the reader if he has not already a satisfactory idea of what is meant by the term. In fact, a little thought will convince one that it is not easy to define time in other terms, nor is it a simple matter to state what we know about it. It will not be profitable to enter into a discussion here respecting its existence in the abstract. It is sufficient to observe that if a number of events are under consideration the relations of their occurring are such that everyone can arrange them in the same unique order. That is, in the case of two events A and B, everyone can say that A existed when B did not exist and that when B existed A existed also; or, we have a definite idea of the order of their occurring, and so on for any number of events. The point to be noticed here is that there is universal agreement in the question of order, at least in cases which offer no observational difficulties.

It must not be inferred, however, that the question of order is all that is involved in time, for time is supposed to be measurable, while order is not. The difficult question relates to the intervals between events. We have a more or less vivid impression that there is an interval between two events, which is probably induced by the consciousness that a number of other events have occurred between them, such as something we can hear or see, or, perhaps, such physiological processes as the number of heart beats or the number of mental acts. But this impression is not of the same certain character as the idea of order. If many persons observe two events A and B and then two others C and D, they will not in general agree among themselves as to the relation between the interval A B and the interval C D. The estimate of the interval in the two cases depends upon a multitude of things such as the comfort of the individual, and his physical and mental activity. Everyone remembers how a few days of travel, especially when he was young, amid unfamiliar surroundings, have seemed like ordinary weeks of time, and how he marveled on his return that he did not look as strange to his friends as they did to him. The multitude of new experiences gave the impression of great length of time. For similar reasons short dreams often seem to fill hours or even days of time. It is clear

that such indefinite methods of estimating time as these are of very little scientific value.

It will be found that the estimates of various observers agree more nearly the more fully they base them upon counts of the occurrences of simple phenomena. It will be perceived at once that this implies that they have supposed that the simple events observed have occurred at equal intervals, or perhaps in rare cases in unequal but simply related intervals. This being the basis of our ideas of intervals of time, and the only way of measuring them, it remains to simplify the method and make it precise. To do this it is only necessary to select some event which is repeated an indefinite number of times in such a manner that it will occur after, in a sense of order, any event of another kind, and such that it can be universally observed.

It may be stated without further remarks that equal intervals of time are defined by Newton's first law, or axiom, of motion, which affirms that *a body subject to no forces moves uniformly in a straight line.* That is, two intervals are equal by *definition* if a moving body which is subject to no forces passes over equal distances in them. It is impossible practically to realize the condition stated in the law, but the indirect consequences of it are of great simplicity. It follows from this and the other laws of motion that the Earth rotates uniformly. (The possible corrections to this statement are discussed in the next section). Therefore the rotation of the Earth becomes not only the practical measurer of time but as a result of Newton's laws, the definition of what is meant by equal intervals of time. If it were not a definition its correctness could be tested. But it is well known that if anything, such as a clock, disagrees with the rotation of the Earth, it is at once assumed to be wrong. The only sensible method of testing it would be to compare its rotation with some other simple consequence of Newton's laws, such as the rotation or revolution of some other planet. If there were a disagreemeut it would show that one or the other of the bodies is subject to effective exterior forces not taken into account.

It will be observed that this definition of duration, which is at the bottom of every method of measuring time, does not depend upon any particular conception of time in the abstract; indeed, if any such thing as time independent of physical phenomena exists, it is quite possible that this definition may disagree with it.

Possible Changes in the Standard of Time.

As has been stated, time is practically measured by the rotation of the Earth, while the definition of equal portions of it is

contained in Newton's first law of motion. If the forces to which the Earth is subject cause it to rotate non-uniformly on the basis of the Newtonian laws, then the practical standard of time will be variable with respect to that basis. Are there forces at work upon the Earth (the Newtonian law will henceforth always be assumed to give the standard) which change its rate of rotation?

The Earth is rotating in the luminiferous ether and a considerable quantity of meteoric matter. The latter, if not the former, offers some resistance to its motion, and causes it to rotate more slowly, just as friction causes the rotation of a top to die out. But this resistance is exceedingly feeble and will produce no measurable results for thousands of years. It would produce sensible results in the revolution of the Earth much more quickly, but even there the effects are inappreciable.

As the Earth loses its interior heat it undoubtedly shrinks a little. The effect of this change in size is to make it rotate faster, but the increase of motion is exceedingly slight.

The Sun and Moon generate tides in the Earth which move around in the westward direction. Since the Earth rotates eastward the impact of these tidal waves on the shores and the friction they encounter in passing along the oceans retard the rotation of the Earth. These effects are again very small.

Changes in the form of the Earth such as the elevation and subsidence of continents, or the less important alterations produced by erosion, or the evaporation of quantities of water and subsequent condensation in another latitude produce slight changes in the rotation of the Earth. In fact, if any mass is moved so that its distance from the axis of the Earth is changed, and no compensating shifting is made, the rate of rotation of the Earth is altered.

The important question is whether these changes are sensible. Those due to the causes last mentioned are not only exceedingly minute but they nearly, if not exactly, balance each other. Those due to the first and third causes are constantly in the same direction while that due to the second cause continually opposes them. It is very difficult to determine their precise effects quantitatively, but they are certainly so minute that they do not change the length of the day by a second in ten thousand years. Therefore, if one be divided by the number of days in ten thousand years a number will be obtained which will be greater than the difference between any two successive days when it is expressed in seconds. It is evident that this is an interval so small that it is absolutely inappreciable; hence the rotation of the Earth may be taken as

giving the same results within the limits of observation as Newton's first law of motion.

One difficulty remains to be mentioned which might be easily overlooked. It has been tacitly assumed that it is possible to determine when the Earth has completed a rotation, but this is clearly impossible unless a fixed direction in space, not parallel to the Earth's axis, is known. Now there are no known fixed points or lines in space by means of which a fixed direction can be determined, but it is *assumed* that the stars do not, on the average, move in any angular direction with respect to the Earth. Hence it is necessary to admit the assumption, which of course appears most reasonable, in order to make use of the rotation of the Earth as a means of measuring time.

It should be remarked that if one should attempt to apply the definition contained in Newton's law a corresponding difficulty would be encountered. In this case it would be necessary to determine in some way a fixed point in space from which to measure the distances, a difficulty which is less easily overcome by any reasonable and practical assumption.

Sidereal Time and Solar Time.

Sidereal time is measured by the rotation of the Earth with respect to the stars, and solar time by the rotation of the Earth with respect to the Sun. Because of the Earth's revolution around the Sun, the Sun appears, as seen from the Earth, to move eastward among the stars, completing a revolution with respect to them in a year. Now suppose the Sun and a star are on the meridian at a given time; after a certain interval the Earth will have turned so that the star is again on the meridian. This interval constitutes the length of a sidereal day, all of which are almost exactly of the same length, as has been explained above. But at the end of this interval the Sun will have moved nearly a degree eastward and will therefore lack a little of being on the meridian. It takes nearly four sidereal minutes for the Earth to turn enough more to bring it on the meridian. When it has arrived there a solar day has elapsed.

Shortest Solar Days and Longest Solar Days.

The Earth moves faster when it is near the Sun than when it is more distant; consequently the apparent motion of the Sun among the stars is not uniform. Besides this the Sun has a northward and southward motion, which at times decreases the eastward motion. Hence, for these two reasons, the apparent eastward motion of the Sun among the stars, which alone makes the

solar day longer than the sidereal, is irregular; and there is a corresponding variation in the lengths of the solar days. The lengths of the days vary in quite a complicated manner, though the extreme difference is not very large.

The longest day in the year is December 22d (it may vary by a day from this date because of the leap year once in four years) which is $4^m\ 26^s.5$ longer than the sidereal day when the difference is expressed in sidereal time. Thus, the day which has the least time of sunlight for positions in our latitude, and which in ordinary speech is spoken of as the shortest day in the year, is actually the longest from the time the Sun is on the meridian until the Sun is on the meridian again. From December 22d the solar days constantly decrease in length until March 26th, when they are only $3^m\ 38^s$ longer than a sidereal day. From March 26th the solar days increase in length until June 20th, when they are $4^m\ 9^s.5$ longer than the sidereal day. From June 20th the solar days again decrease in length until September 17th, which is the shortest day in the whole year, being only $3^m\ 35^s.2$ longer than the sidereal day. The difference in length between the longest day and the shortest day is therefore about $51^s\ 3$ of sidereal time. From September 17th until December 22d the solar days constantly increase in length.

The average length of the solar days, which is $24^h\ 3^m\ 56^s.556$ in sidereal time, is called the mean solar day. This is the time in actual use, being divided into twenty-four mean solar hours, and from this point on all references to time will be to mean solar time. Mean solar days are all of the same length, with the same approximation that sidereal days are of the same length, and ordinary time-pieces are made to keep this time as nearly as possible. It would be very difficult, if not impossible, to construct a clock which would keep true solar time with any high degree of accuracy.

Local Time and Standard Time.

The mean solar time of a place is called its local time. All places having the same longitude have the same local time, but places having different longitudes have different local times. In going around the Earth, a distance of about 25,000 miles, the difference is twenty-four hours; consequently at the Earth's equator, seventeen miles in longitude correspond to about one minute in time. In our latitude the circumference of the Earth along a parallel of latitude is considerably less, and twelves miles correspond to about one minute in time. Hence the difference in local

STANDARD TIME BELTS IN THE UNITED STATES.

time between places on the Atlantic coast and those on the Pacific coast, which are separated by nearly 3,000 milles, is about four hours.

In order to avoid the endless confusion, and in some cases danger, that would follow if places comparatively near together should have sensibly different time, it has become quite customary for all places which do not differ more than about half an hour in local time from that of some convenient meridian to use the local time of that meridian. Thus, while the extreme difference in local time of places using the same time is about an hour, the error in either of them is only half an hour. In this manner a strip of country about 720 miles wide east and west uses the same time, and the next strip of the same width an hour different, and so on. This time is called *standard time*, and it differs from the local time except in one meridian in each strip.

In the United States there are four hours of standard time used. The eastern portion uses Eastern Time which is the local time on the 75th meridian west from Greenwich, which runs through Philadelphia. At places east of this meridian it is later by local time than by standard time, the difference being about one minute for twelve miles. Thus at New York, on the basis of local time, standard clocks are four minutes slow, at Boston sixteen minutes slow, etc. At places west of this meridian, but in the

eastern time division, standard clocks are correspondingly fast, the difference being nearly twenty minutes at Pittsburg. West of Buffalo, and a line running irregularly northward and southward through it, Central Time, which is the local time of the 90th meridian, is used. This meridian passes very near St. Louis. Standard clocks of places east of this are slow, the difference being nearly twenty-five minutes at Cincinnati and about ten minutes at Chicago. The western limit of Central Time extends through the Dakotas and northwestern Texas. The next division westward is called Mountain Time, and is the local time of tht 105th meridian, which passes through Denver. This division of time is used west as far as Ogden. The next is Pacific Time, the local time of the 120th meridian which is about 100 miles east of San Francisco. As the intervals between the standard meridians are in all cases 15 degrees of longitude, which equals one hour of time, there is a difference of one hour between one division of time and the next; If the exact divisions were used the boundaries between one time division and the next would be meridians 7.5 degrees east and west of the standard meridians. As a matter of fact the railroads, which furnish local time to most places, and to which most people look for correct time, use dividing points between the divisions of time according to their own convenience. It obviously would be unwise to have railroad time change during the run of a given engineer. Hence railroad time changes at the most convenient place near the boundary of the time division, that is, at the nearest point where engineers change. As a result, the boundaries of the several time divisions as used are very irregular, and vary in many cases very strikingly from the standard divisions. (See map page 398).

Although this very convenient system was adopted in 1883 and is in universal use by railroads, yet many people, and even schools, persist in creating confusion by using local time. In some cities one has to allow a margin of twenty minutes in appointments because of the uncertainties due to this chaotic state. It is perfectly clear that standard time is in every respect just as good as any and that it has the immense advantage of being uniform over large sections of country. Let educated people, who above all others should consciously direct their activities in the direction of reforms, not hinder advances inaugurated by commercial interests; instead of being paralyzed with conservatism let them become the leaders of progress.

DISTRIBUTION OF TIME.

The accurate practical determination of time and its distribu-

tion are problems of much importance. There are several methods of determining time, but the one in common use is to observe the transits of stars across the meridian, which gives the sidereal time, and then, from the mathematical theory of the motion of the Sun, to compute the mean solar time. It might be supposed that it would be simpler to observe the transit of the Sun, but it is not so. In the first place it is much more difficult to determine the exact time of the transit of the Sun's center than it is the time of the transit of a star, and it occurs but once in twenty-four hours while many stars may be observed; in the second place, it gives true solar time instead of mean solar time, and its correction is as difficult as that required in the other method.

It remains now to explain how time is distributed from the observatories where the observations are made. The chief source of time for railroad and commercial purposes is the Naval Observatory at Georgetown Heights, Washington, D. C. There are three clocks keeping standard time at this observatory. At night the errors of the three clocks are found from observation, and, after applying this correction, the mean of the three is taken as giving the true standard time for the succeeding twenty-four hours. At five minutes before noon eastern time the Western Union Telegraph Company suspends its ordinary business and throws its lines into electrical connection with the standard clock at the Naval Observatory. An arrangement is made so that the sounding key makes a stroke every second during these five minutes except the twenty-ninth second of each minute, the last five seconds of the first four minutes, and the last ten seconds of the fifth minute. This gives the opportunity to make ten determinations of the error of a clock at any point. To simplify matters clocks are made which are automatically regulated by these signals, and there are at present more than 30,000 of them in use in this country.

These noon signals also operate time balls in fifteen ports in the United States. This device consists of a large ball being dropped at noon, eastern time, by means of electrical connection with the Naval Observatory, from a considerable height, at conspicuous points.

The time signals are sent out from the Naval Observatory with an error usually less than two-tenths of a second, but this is frequently considerably increased by the system of relays which must be used to reach great distances. Probably the greatest source of error, except in the case of those automatically regulated, is in setting the clocks by the signals.

The time service just described reaches directly nearly all parts of the country east of Ogden. West of Ogden time is distributed in the same manner from the Mare Island Navy Yard, California. Besides the government sources, the Allegheny Observatory furnishes time to the Pennsylvania railroad; the Goodsell Observatory, of Northfield, Minn., to the Great Northern, the Northern Pacific, the Great Western and the "Soo" lines; the Lick Observatory, to the Southern Pacific system. Many other observatories furnish time for local purposes, and practically every one keeps its own time.

THE LARGE NEBULOUS AREAS OF THE SKY.

H. C. WILSON.

As bearing upon the question of the origin of our solar system and of other stellar systems, the existence at the present time of enormous areas of exceedingly faint, diffuse, nebulous or cloud-like matter in the heavens is of important significance. According to the "Nebular Hypothesis" the Sun, planets, and stars have been formed by the aggregation and condensation of just such matter, which is supposed to have originally filled all space. If this hypothesis be true, it would be strange if there were not still much of the original cosmic matter still scattered through the interstellar spaces. In fact we do find several thousand little patches of faint cloud-like light distributed here and there over the sky and we call them, for want of a better name, nebulæ. The spectroscope shows many of them to be composed of glowing gas, a mixture possibly of hydrogen and some unknown gases. Others yield the spectra of glowing solids and we infer them to be either clusters of stars so remote that the individual stars are beyond the limit of vision with our telescopes, or immense clouds of small particles of matter glowing from some unknown cause.

All of the nebulæ, so far as yet determined, are at vast distances from us, so that although they are really enormous in extent they cover only small areas of the sky. The largest is the Great Nebula of Andromeda, which covers an oval area about 2° long and 1° wide.

In addition to the nebulæ which can be seen or photographed, with comparatively definite outlines, there are a few much larger patches of very diffuse, exceedingly faint light in certain parts of

the sky. They are too large and faint for their outlines to be detected with a telescope, and they cannot be photographed with an instrument of too great focal length. They require a camera of great light-gathering power, short focus, and wide, flat field. There is but little contrast between their light and that of the general illumination of the sky, produced by the reflection of the starlight from dust and frost particles in our atmosphere, so that a very little haze obliterates them entirely.

The most remarkable regions of this kind now known are in the constellations Taurus, Orion and Scorpio and photographs by Pickering, Barnard, Wolf and the writer of this note agree in the main details of the nebulosity in these regions, so that there can be no doubt as to its existence. Around the Pleiades in Taurus the nebulosity extends about 5° to the north, west and south, and 7° or 8° to the east from the group of stars. In Orion nearly the whole constellation is involved in a vast field of nebulosity, of which the "Great Nebula of Orion" is but the central part.

Sir Wm. Herschel saw fragments of these nebulosities in his sweeps of the heavens and recorded the positions of 52 regions of the sky in which he saw, or suspected that he saw, very faint milky light in the background of the stars.

Seven of Herschel's regions are in Orion and six in Taurus, but only one of those in Taurus is in the vicinity of the Pleiades which has been so much photographed. Curiously, in the spot indicated by Herschel the nebulosity is not so bright as it is in the same declination about 20 minutes toward the west, but if I identify the location correctly, it is in a space almost void of stars, so that the faint light would be more noticeable there than in other regions where the stars were more numerous. In Orion Herschel's regions are found to coincide closely with some of the brighter parts of the nebulosity shown by the photographs, but the latter show a far greater extent than Herschel was able to detect.

Herschel says of his observations: "When these observations are examined with a view to improve our knowledge of the construction of the heavens, we see in the first place that the extensive diffused nebulosity is exceedingly great indeed; for the account of it, as stated in the table, is 151.7 square degrees; but this, it must be remembered, gives us by no means the real limits of it, neither in the parallel nor in the meridian; moreover, the dimensions in the table give only its superficial extent; the depth or third dimension of it may be far beyond the reach of our telescopes; and when these considerations together are added to

what has been said in the foregoing article, it will be evident that the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination."

In these words Herschel expressed no doubt of the reality of what he saw, and if he could have seen the photographs which I have at hand as I write of the Pleiades and Orion regions he would have felt that his words were abundantly justified. Either of these two regions contains more than the 150 square degrees of nebulous area which he assigned to his 52 regions.

On the other hand Dr. Isaac Roberts, the foremost of the English celestial photographers, who has done marvelously good work in photographing the nebulæ and star clusters, after photographing the entire list of 52 nebulous regions, says, in *Monthly Notices*, R. A. S., LIII, 1, "Of the fifty-two nebulous regions described by Herschel, the photographs show diffused nebulosity on four of them only." The four are a part of the Great Nebula of Andromeda, the region around ζ Orionis, and two parts of the "America" nebula in Cygnus, all comparatively bright and well known. Dr. Roberts failed to get any of the nebulosity around the Pleiades and also the greater part of that in Orion. This failure instead of being totally discouraging leads us rather to believe that Dr. Roberts' work was not done under the most favorable conditions, and that therefore there is hope that under better conditions more of these regions given by Herschel may be proved by photographs to be nebulous.

I have been much interested in these enormous nebulous areas for several years past and have obtained a number of photographs, especially of the Pleiades region, with our Brashear 6-inch star-camera and with the 2½-inch Darlot lens, which show the nebulosity quite distinctly. Two of the Pleiades' photographs were reproduced by the half-tone process in POPULAR ASTRONOMY for Feb. 1899, Plate II. A later photograph, taken on the nights of Nov. 7 and 8, 1899 with the six-inch camera and a total exposure of seven hours, is herewith given (Plate XI). It shows more of the nebulosity than the other two, verifying nearly all that was shown in them and adding considerably to the extent of the nebulosity especially to the eastward. The darkening toward the lower right hand corner of the plate is due to the too narrow opening of the dome, the field being partially cut off in that direction. The Darlot camera, the field of which was clear in that direction, shows a considerably greater extension of the nebulosity to the southwest. In fact it does not appear certain that the limit of the nebulous area has been

reached in any direction. It fades from view toward the edges of the field, partly from a real lack of intensity and partly because the light-gathering and defining power of the lenses declines the farther the object is from the center of the field.

The area covered in the reproduction extends from about 3^h 25^m to 4^h 5^m in right ascension and from 20° to 27° 30′ in declination. The bright star about three-fourths of an inch to the right of the upper left hand corner of the plate is ψ Tauri. Almost directly below this and about an inch from the bottom of the cut is A Tauri. These are the only stars in the region, outside of the Pleiades group, which are as bright as the fifth magnitude.

The distribution of the nebulosity is not at all uniform throughout this region, although plainly the whole region is filled with it. There are darker spaces, lanes or channels scattered through it which give it a vague resemblance to the Great Nebula of Orion. It will be noticed that there is very little halation around the stars, so that the blotting out of the principal stars in the Pleiades group is due chiefly to the dense nebulosity which surrounds them. This is greatly intensified in the method of making the reproduction. On the original negative the stars are all quite sharp and clear cut and much detail is shown in the nebula within the group. I presume that by manipulation in printing, shielding all of the plate except the bright group, one might bring out these stars in the print together with the exterior nebulosity, but I have done no manipulating of this sort. The sole process used has been to make a contact positive print on glass from the original negative, and a second negative on glass by a contact print from the positive. A silver print on paper was made in the usual way from the second negative, and the engraving was made by the half-tone process from the silver print. Both negatives and the positive were developed with a strong hydrochinon developer, giving great contrast. The original negative was made on an 8 x 10 Cramer crown plate, and the positive and second negative on Seed transparency plates. The reproduction is made on the scale of the original.

Since 1899 I have been so occupied with other duties that I have been able to give very little time to long exposure photographs.

It is therefore with a great deal of pleasure that I see before me this summer the prospect of a little leisure, and above all of the opportunity to experiment in celestial photography at a high altitude. Through the courtesy of the officials of the Great Northern Railroad, and other friends who have been interested

in our work, Professor Payne and I will be enabled to take our photographic outfit to the mountains in western Montana, and to determine by experiment whether the atmosphere at an altitude of about one mile in that region is better suited to the problem of photographing the faint nebulous areas and the Milky Way, than is the Minnesota air at home at an altitude of about 950 feet.

We plan to start about the last of June and to utilize in our experiments the moonless nights of July and August; and it is our hope to obtain successful photographs of a few of Herschel's nebulous regions as well as of the Milky Way.

THE SATURNIAN SYSTEM.

D. G. PARKER.

FOR POPULAR ASTRONOMY.

Up to 1781 when Sir Wm. Herschel discovered Uranus, the planet Saturn was supposed to mark the outer boundary of our solar system. Although apparently known to the ancients from the morning dawn of history, nothing remarkable was suspected until 1610 when Galileo addressed his quaint message to the Duke of Tuscany, in which he said: "When I view Saturn, it seems tricorps;" the explanation being that his telescope, then just completed, was of insufficient magnifying power to give more than an indefinite right and left glimpse of the great appendages, and these he declared to be "Companions helping old Saturn on his way."

That the planet was known long before even the rudiments of astronomy became a scientific study, is demonstrated by the fact that the earliest mythological conceptions were woven around it, while in naming the days which make up the weekly calendar, Saturn was honored in the suggestive nomenclature.

Of all the major planets known, he is the lightest in density; so light in fact that no object of animal life known to us, could possibly survive in the elements constituting the atmosphere or liquids of that remarkable body.

The majesty of physical and universal law, is happily illustrated by his movements: A body 73,000 miles in diameter, more than nine times that of the Earth, separated from the Sun by the inconceivable distance of nearly 900 millions of miles, flying through space at the startling velocity of six miles per sec-

ond, yet held by a firm grasp to a well defined track more than fifty-five hundred millions of miles in length, and making periodic rounds with critical exactness, "Not an inch out of space, nor a second out of time."

When we consider the magnitude of bulk; its extremely light density, and the rapid revolution upon its axis, (over 22,000 miles per hour) there can be no surprise that the equatorial line exceeds that of the polar, so greatly—(7000 miles). A swiftly turning grindstone may illustrate. Gathering the fluid in its rapid motion, it is thrown off from the central line. So, every inch of extra padding over the equatorial belt of a planet has been irresistibly drawn from the polar extremities by the balancing of gravitating and centrifugal forces.

On each side, and parallel with the equator, may be dimly seen, dark belt markings which change their forms from time to time, and these are supposed to be clouds floating in an atmosphere of great depth. This presumption not only satisfies the observation best, but carries out the analogy with what is more clearly seen upon Jupiter, and what we know exists upon the Earth. The atmosphere of the torrid zone, being warmer and therefore lighter, than that of the polar, this latter is constantly rushing in from both sides to equalize. Meeting, they roll back upon themselves forming the parallel belts as seen.

This is confessedly somewhat speculative, and not knowing thermal, or other conditions as we do here, our speculations are loaded with many elements of uncertainty. The fact is, we are separated by a wide and impassable gulf. It takes large and clear glasses to read a poster 900 million miles away.

Assuming the Sun to be the principal source of heat, it has been estimated that the atmosphere of Saturn is charged with a temperature 90 degrees lower than ours. Doubtless we may never know all the conditions effecting temperature upon the various planets, and we reason therefore from analogy. Our mathematical presumption is, that the reflective power of the Sun, is in proportion to distance. We may be so far removed from the largest body, that it reflects only a point of light, and is finally lost entirely from view. The heat diminishes as the light fades away. With this thought in mind, conclusions may be drawn by noting the comparative size of the Sun as seen from the Earth, and by the Saturnian astronomer. (About 10 to 1).

The reflective surface of Saturn, must include his rings; hence it is apparent that between degrees of ring shading, and the varying distance of the planet from the Earth (741 and 1122

million miles, extremes) there is a marked difference in his brilliancy from time to time.

On the La Place theory of building up in successive order, by nebular process, it is difficult to give a reason why this body should be so much lighter in density than Jupiter; being so much smaller, and separated from the Sun, presumptively, so much earlier. It is a question whether the whole theory may not break down under a close analysis of the varying conditions of these two planets.

Ancient mythology filled Earth and sky with imaginary deities. In this drama of the gods, Saturn was ushered in as the youngest son of Uranus and Gaia. He was afterwards banished by an edict of Jupiter, the chief god, and fled to Latium where he was cordially received by Janus, and invested with equal power on the throne of that sovereignty. His reign was so popular that it became known as "The Golden Age," and the Saturnalia festival given to his honor in December of each year, is an occasion celebrated with great pomp and given to almost unbridled indulgences.

It is doubtless known only to few, other than students in astronomy, that

A COMET FAMILY

of indefinite numbers make periodic excursions between, and around this planet and the Sun. How these come to be drawn in from the outer depths of ethereal spaces and made a part of our solar system, is a subject highly speculative and belongs to a separate paper.

The ponderous Jupiter, midway between Saturn and the Sun, not infrequently contests the allegiance of these excursionists, and notable instances of capture are recorded.

The most remarkable fact concerning this planet is the marvelous number of appendages which go to make up his system. Nature was more than prodigal in his ornamentation. So far as we know, it is the only body in the universe of stars, ring encircled.

MULTIPLICITY OF MOONS.

No other discovered planet is accompanied by more than five moons, while this one is known to have eight, with strong presumptions of three others, yet undiscovered. If then, the La Place doctrine is to be accepted, this planet, after having himself emerged from the Sun, then in turn abandoned no less than 14 nebulous rings. Why such prodigality confined to this one, is a question which will probably never be satisfactorily answered.

With the exception of the most distant satellite, they are all substantially in plane with each other, and with the rings. These rings had been under investigation 45 years before a moon was detected, even then only one, and it was 193 years later, before the last of the eight was gathered in.

The honor of these discoveries is divided between Huyghens and Herschel of England, Cassini of Italy, and Bond of Cambridge, Mass., and it would seem that, "The end is not yet," for it is a fair mathematical conclusion that at least three other satellites remain undiscovered; that is to say, under a presumptive law suggesting planetary distances, the wide space between No.s 5 and 6, calls for one, while it requires two, if not three, to complete the spacing between 7 and 8.

If we call these Saturnian satellites, companions, it would seem to be a misnomer, for none of them are within hailing distance or on speaking terms. No. 1 is about 117,000 miles from the planet while No. 8 stretches away nearly two and one-half millions of miles. Nevertheless, however distant and formal, they are not without respectful recognition, for every transit causes perturbating sensitiveness, and the resistless power of attraction is felt in proportion to size and distance.

MYTHICAL FANCIES.

I have spoken of the fanciful inagery with which the ancients clothed nearly every material thing in Earth and sky, and so deeply impressive was this, that the learned masters of modern times have borrowed largely to embellish their own works. In selecting names for these satellites, they were deeply colored with these fascinating myths.

No. 1, *Mimas*, is a Trojan, having contemporaneous birth with Paris.

Enceladus, the next, seems to be an exception in these mythical embellishments.

Tethys is very romantic. As the wife of Oceanus, god of Ocean currents, she became mother of all the chief rivers in the universe, as also the oceanides or sea nymphs.

Dione was one of the wives of Zeus, the superintending god.

Rhea was one of the six Titan daughters born to Uranus. She was espoused to Saturn and became the mother of Vesta, Ceres, Juno and Pluto.

Titan was the oldest son of Uranus. A conflict with his younger brother, Saturn, arose as to their respective right of sovereignty over gods and men, which was finally settled by Jupiter in favor of the latter.

I pause here to note that the estimated diameter of this moon, (3500 miles) which Professor Barnard challenges, gives it the dignity of a world considerably larger than the planet Mercury.

Hyperion is known as the god of day, and father of Sun and Moon. Notwithstanding this mythical exaltation, he is doubtless the smallest of the celebrated group.

Japetus was the fifth son of Uranus and father of Atlas and Prometheus. He swings upon the outer boundary, and has excited the wonder of astronomers in the variability of his brilliancy, as well as the remarkable inclination in the plane of his orbit.

THE RINGS OF SATURN.

No object in the heavens has awakened more interest or excited greater discussion than the rings of this planet. Saturn is the only known body arched with such an appendix or encircled by a brilliancy so remarkable. Of the many theories advanced as to their composition, that of Professor Maxwell (meteoric) has become most popular and will doubtless stand the test of analysis.

Why have not these rings condensed into moons? This is answered by the late Professor Roach who showed that a body brought within a given distance of its primary's radii, would be torn into fragments between the gravitating and centrifugal forces. These rings are found to be within the destructive limit.

Advocates of the nebular hypothesis point to these flaming arches as a practical demonstration of their theory, which it is not the purpose of this article to affirm nor deny; but there are some interesting speculations as to possible changes going on, which it is not out of place to note.

Observations by the leading astronomers from 1657 to 1851, uniformly concurred in raising a suspicion that gravity is overcoming the centrifugal force, and that it is only a question of time when the whole will be precipitated upon the central body. They even gave the rate of approach, and the approximate time of the great catastrophe. I need not say that the distinguished scientists of our times, do not share this alarm.

But if true, how terrible will be the bombardment! The steady approach of these flying missiles will only increase their velocity until finally grazing the surface they will ricochet through several revolutions until the centrifugal force is exhausted. This is succeeded by the next zone, and still the next, through successive centuries. Can one imagine the fury of such a storm or the violence of such an impact?

Wait a moment. We will not waste our sympathy upon the poor denizens of that unfortunate world. There will be no such calamity. I have been reasoning as if the planet is without atmosphere. Let us take another view. From analogy, as also the cloudy belts witnessed, we may assume that Saturn has an atmosphere, upon entering which, the flight of these meteors will be immediately arrested, with the result of a momentary flash, and then they will be lost in utter extinguishment. What has become of them? They are totally consumed by atmospheric friction.

It is needless to say that meteors are not confined to the rings of Saturn. The celestial spaces are packed, so to speak, with these strange wanderers. It is estimated by high authority, that more than fifteen millions are encountered by our planet daily, and yet we rest quietly unconscious of danger. Such is the protecting shield of atmosphere.

Shall we speak of scenery? We instinctively enjoy the beauties of nature as revealed in our own surroundings, but what shall be said of scenery a thousand times more gorgeous.

For a moment allow ourselves to be transported to the planet Saturn. In one of the zones corresponding to our temperate one, we stand appalled at the startling grandeur, above, beneath, around. We are dazzled by the electrical splendor.

Eleven, possibly twelve moons, as varied in size as they are in distance, chase each other in quick succession across the sky, while within the orbit of these stands a flaming arch nearly 50,000 miles high, covering the whole planet with a reflective briliancy which no pen can picture nor tongue describe.

PORT ARTHUR, Texas.

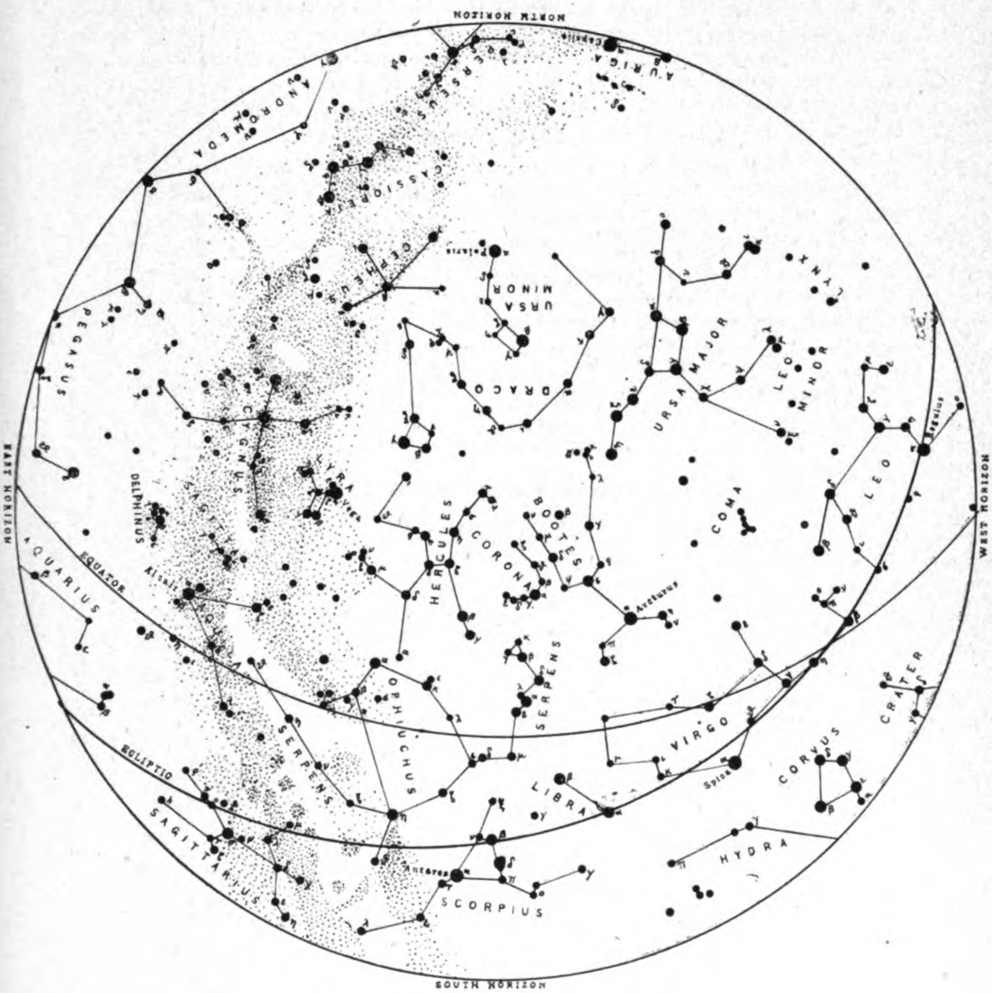
PLANET NOTES FOR JULY AND AUGUST.

H. C. WILSON.

Mercury will be at superior conjunction July 9 and so will not be visible during this month, but about the middle of August it will become visible in the evening, reaching greatest eastern elongation August 19. Mercury will be in conjunction with Mars on July 2, with Neptune July 4 and with Venus July 10, but at that time all four planets will be hidden in the glare of the Sun.

Venus will be at superior conjunction July 8 at 1 A. M., Central Standard time, and will be hidden in the rays of the Sun during the greater part of July. In August she will be evening star, but will not be far enough out from the solar glare to be easily observed.

Mars will be morning star during these months, and at a high northern declination, but not far enough from the Sun for satisfactory observations. Mars and Neptune will be in conjunction on the morning of July 9.



The Constellations at 9 p. m. July 1, 1904.

Jupiter will be at quadrature, 90° west from the Sun, July 21, and may be observed in the morning hours during the summer months. He will be at the stationary point in his apparent path on Aug. 20.

Saturn is in as good position as he can have this year, during these two months. He will be at opposition Aug. 10, and is to be seen any clear morning now in the constellation Capricornus. The rings are plainly visible, and when the seeing is good the details of structure can be made out. Three or four satellites are always visible and sometimes five or six may be seen with a small telescope.

Uranus is also in good position for study, except for the fact of his low altitude. He may be easily found with a small telescope, close to the ecliptic in the western part of the constellation Sagittarius.

Neptune being just past conjunction will not be in position for observation during these months.

The Moon.

Phases.		Rises.	Sets.
		(Central Standard Time at Northfield. Local Time 13m less.)	
1904		h m	h m
July 4-5	Last Quarter	11 39 P. M.	12 13 P. M.
12	New Moon	4 13 A. M.	7 19 "
19	First Quarter	12 32 P. M.	11 49 "
26-27	Full Moon	7 9 "	5 13 A. M.
Aug. 3- 4	Last Quarter	11 6 "	1 02 P. M.
11	New Moon	5 17 A. M.	7 27 "
17	First Quarter	12 37 P. M.	11 04 "
25-26	Full Moon	6 50 "	6 00 A. M.

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	Immersion. Washington M.T. h m	Immersion. Angle f'm N pt. °	Emersion. Washington M.T. h m	Emersion. Angle f'm N pt. °	Duration. h m
July 1	B.A.C. 7697	6.8	10 01	102	11 03	231	1 02
21	η Libræ	5.5	6 39	94	8 2	302	1 23
22	24 Scorpii	5.2	8 56	52	9 56	326	1 00
25	ρ^2 Sagittarii	6.1	8 25	78	9 50	277	1 25
25	B.A.C. 6658	7.0	13 12	151	13 33	182	0 21
Aug. 5	48 Tauri	6.4	12 11	92	13 02	241	0 51
5	γ Tauri	3.9	13 56	93	14 55	236	0 59
5	70 Tauri	6.3	17 09	112	18 14	217	1 05
20	Y Sagittarii	Var.	12 27	71	13 32	274	1 05
23	W.B. xx, 1293	6.0	15 19	114	16 06	209	0 47
24	λ Capricorni	5.4	15 33	32	16 27	286	0 54

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered by	at	Local M. T.		R. A.	Decl.	Mag.
				h m	h m	° ′	
1902 NU	Wolf	Heidelberg	1902 Mar. 10	13 54 9	12 52.1	— 6 17	13
1894 NV	"	"	1904 Apr. 11	13 55.9	13 55.5	+ 0 32	12.6
1904 NW	"	"	12	11 16.9	13 55.4	— 2 06	12.6
1904 NX	"	"	16	10 25.9	13 08.3	+ 28 49	13.0
1904 NY	"	"	20	11 11.4	13 53.0	+ 18 23	9.2
1904 NZ	Dugan	"	19	10 00.0	14 12.1	— 7 50	13.2
1904 OA	"	"	19	13 21.0	13 57.6	— 7 17	13.0
1904 OB	Wolf	"	21	12 56.4	14 47.0	— 0 41	13.2

Comet a 1904 (Brooks.)—The new comet is still visible with a telescope but is slowly growing fainter. It is following closely the approximate course indicated by continuing the line drawn on our diagram in the last number of POPULAR ASTRONOMY. Another set of elliptic elements has been computed by Messrs. Ralph H. Curtiss and Sebastian Albrecht, using Professor Leuschner's "Short Method." This time the eccentricity comes out 0.575 and the period 15.14 years instead of 3.02 years. Later observations indicate that with a longer arc of the orbit the eccentricity and the period will be greater. The fact that the inclination of the orbit is 125° would *a priori* suggest that the comet is not one of short period, for no known periodic comet has a retrograde motion around the Sun.

Professor Leuschner makes the following statement concerning the use of his method (Lick Obs. Bulletin No. 55): "The advisability of determining an orbit from a short arc without hypothesis as to the eccentricity might be questioned, were it not for the fact that in applying the 'Short Method' the aim is to determine as rapidly as possible a finding ephemeris which accurately represents the given observations, the computation of the elements being incidental to conform to established custom. The fact that such an ephemeris, as far as comets are concerned, can thus be derived more conveniently than by means of a preliminary parabola is sufficient justification for departing from the old method. In many cases the periodic character of an orbit is readily revealed from a short arc."

ELEMENTS OF COMET *a* 1904.

Computers: Curtiss and Albrecht.

Epoch 1904 April 22.77234

$$\begin{aligned} M_0 &= 4^\circ\ 16'\ 58'' \\ \omega &= 47\ \ 39\ \ 53 \\ \Omega &= 274\ \ 10\ \ 26 \\ i &= 115\ \ 22\ \ 32 \end{aligned} \Bigg\} 1904 \qquad \begin{aligned} e &= 0.57512 \\ \log a &= 0.78661 \\ \mu &= 234''.47 \end{aligned}$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1904	True α h m s	True δ ° ′	log Δ	Brightness.
May 3.5	16 00 29	+ 53 24.8	0.33644	0.91
7.5	15 43 07	54 57.1		
11.5	15 24 50	56 10.9	0.34822	0.85
15.5	15 06 06	57 05.7		
19.5	14 47 22	57 41.9	0.36419	0.78
23.5	14 29 09	58 00.6		
27.5	14 11 46	58 03.8	0.38306	0.71
31.5	13 55 33	57 55.6		
June 4.5	13 40 51	57 31.9	0.40359	0.63
8.5	13 27 35	57 01.1		
12.5	13 15 52	56 24 2	0.42474	0.56

Parabolic elements have been calculated by several computers and seem to represent the observations well. The latest, which have come to hand as we are about to go to press, are by Mr. Everett I. Yowell, computer at the U. S. Naval Observatory.

The accompanying diagram, prepared by the Junior class in Practical Astronomy at Carleton College shows well the relation of the comet's orbit to those of the planets. At perihelion, about the first of March, the comet was as far from the Sun as is the average asteroid; it was nearest the Earth in April and is now receding from us. It must in reality be quite a large comet, appearing

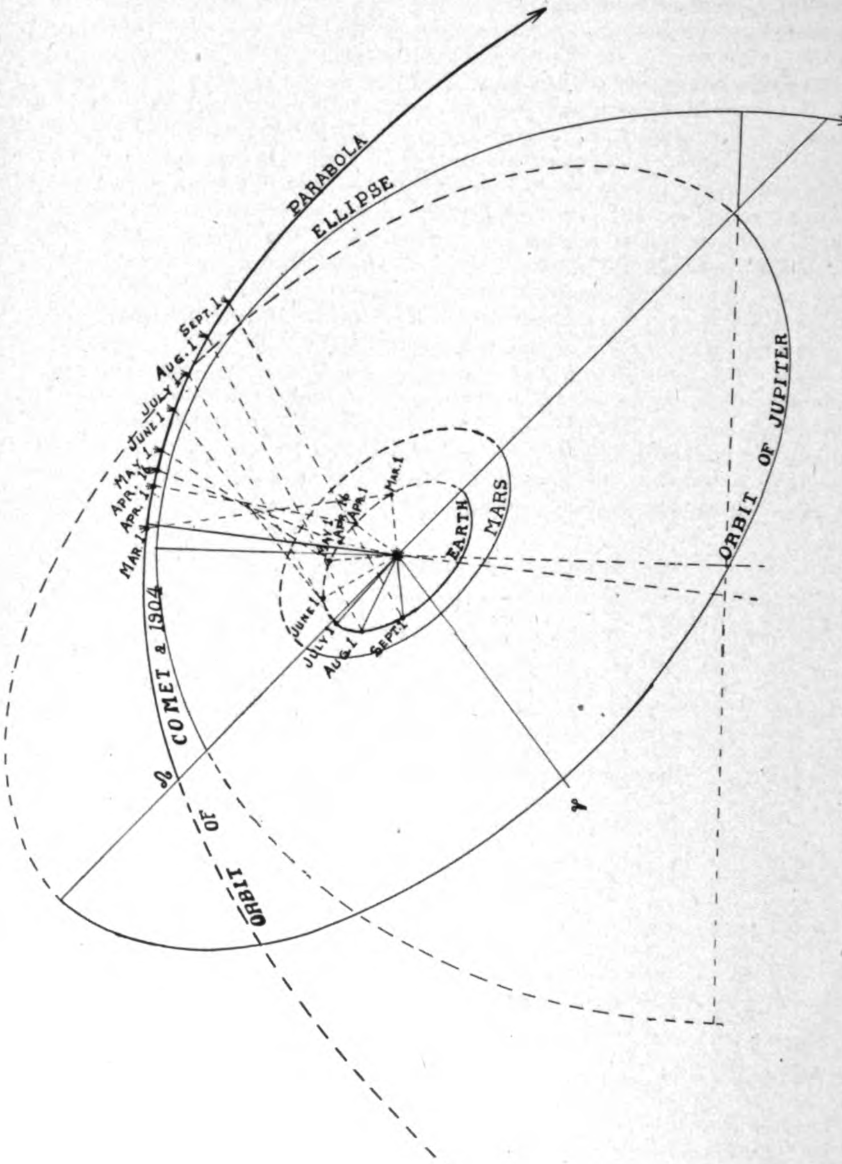


DIAGRAM SHOWING THE RELATION OF THE ORBIT OF COMET *a* 1904 TO THOSE OF THE PLANETS EARTH, MARS AND JUPITER.

small to us because of its great distance. The half ellipse shown is drawn from the elements of Curtiss and Albrecht and the parabola from Yowell's elements.

Elements and Ephemeris of Comet *a* 1904 (Brooks.)—The following parabolic elements were obtained from normal places formed by combining observations made at the U. S. Naval Observatory on April 17 and 18, 22 and 23, 30 and May 1:

$$T = 1904 \text{ March } 5.7688 \text{ G. M. T.}$$
$$\left.\begin{aligned}\pi &= 328^\circ\ 43'\ 47''.6\\ \Omega &= 275\ \ 41\ \ 22\ .8\\ i &= 125\ \ \ 6\ \ 17\ .4\end{aligned}\right\}1904.0$$
$$\log q = 0.431988$$

HELIOCENTRIC COORDINATES.

$$\begin{aligned}x &= r\,[9.764001] \sin (223^\circ\ 12'\ 40''.0 + v).\\ y &= r\,[9.994756] \sin (300\ \ 33\ \ 10\ .4 + v).\\ z &= r\,[9.918342] \sin (24\ \ 29\ \ 22\ .0 + v).\end{aligned}$$

EPHEMERIS.

G. M. T.	α h	m	s	δ °	′	″	log Δ	Brightness.
June 1.5	13	52	13.3	+ 57	59	1	0.41797	0.67
2.5		48	28.5		54	27	0.42060	0.66
3.5		44	49.1		49	17	0.42324	0.65
4.5		41	15.2		43	31	0.42560	0.64
5.5		37	46.8		37	12	0.42855	0.64
6.5		34	24.0		30	22	0.43122	0.63
7 5		31	6.9		23	3	0.43389	0.62
8.5		27	55.3		15	16	0.43657	0.61
9.5		24	49.3	57	7	4	0.43926	0.60
10.5		21	49.0	56	58	27	0.44194	0.59
11.5		18	54.2		49	29	0.44462	0.58
12 5		16	4.9		40	11	0.44730	0.57
13.5		13	21.1		30	34	0.44998	0.56
14.5		10	42.6		20	40	0.45266	0.56
15.5		8	9.4		10	31	0.45532	0.55
16.5		5	41.5	56	0	7	0.45798	0.54
17.5		3	18.6	55	49	30	0.46064	0.53
18.5	13	1	0.8		38	42	0.46328	0.52
19.5	12	58	47.9		27	43	0.46591	0.52
20.5		56	39.8		16	36	0.46753	0.51
21.5		54	36.4	55	5	20	0.47014	0.51
22.5		52	37.6	54	53	57	0.47374	0.50
23.5		50	43.2		42	28	0.47632	0.49
24.5		48	53.2		30	55	3.47889	0.48
25.5		47	7.4		19	17	0.48144	0.48
26.5		45	25.8	54	7	35	0.48397	0.47
27.5		43	48.2	53	55	51	0.48649	0.46
28.5		42	14.5		44	5	0.48899	0.46
29.5		40	44.6		32	18	0.49147	0.45
30.5		39	18.3	53	20	30	0.49394	0.45
July 4.5	12	34	8.3	+ 52	33	21	0.50358	0.42

The brightness at the date of discovery is adopted as the unit. Comparison with an observation made here May 16 gives as corrections to the ephemeris: $\Delta\alpha = -3^s$, $\Delta\delta = +16''$.

EVERETT I. YOWELL.

[Communicated by Rear-Admiral C. M. Chester, U. S. N., Superintendent].

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

July 2	12	31	A. M.	I Sh. In.
	1	52	"	I Tr. In.
	2	46	"	I Sh. Eg.
	4	5	"	I Tr. Eg.
3	1	14	"	I Oc. Re.
7	12	23	"	II Sh. Eg.
	12	38	"	II Tr. In.
	3	06	"	II Tr. Eg.
8	3	21	"	III Oc. Dis.
9	2	26	"	I Sh. In.
	3	48	"	I Tr. In.
11	12	30	"	I Tr. Eg.
14	12	27	"	II Sh. In.
	2	59	"	II Sh. Eg.
	3	17	"	II Tr. In.
15	1	43	"	III Ec. Dis.
	3	51	"	III Ec. Re.
16	12	51	"	II Oc. Re.
17	1	30	"	I Ec. Re.
18	12	13	"	I Tr. In.
	1	2	"	I Sh. Eg.
	2	25	"	I Tr. Eg.
	11	30	P. M.	III Tr. Eg.
	11	33	"	I Oc. Re.
21	3	03	A. M.	II Sh. In.
23	12	39	"	II Ec. Re.
	12	59	"	II Oc. Dis.
	3	26	"	II Oc. Re.
24	3	24	"	I Ec. Dis.
25	12	42	"	I Sh. In.
	2	06	"	I Tr. In.
	2	56	"	I Sh. Eg.
26	1	27	"	I Oc. Re.
	1	42	"	III Tr. In.
	3	27	"	III Tr. Eg.
	10	47	P. M.	I Tr. Eg.
28	12	48	A. M.	II Ec. Dis.
	3	14	"	II Ec. Re.
	3	33	"	II Oc. Dis.
Aug. 1	12	15	"	II Tr. Eg.
	2	35	"	I Sh. In.
	11	47	P. M.	I Ec. Dis.
	11	48	"	III Sh. In.
2	2	05	A. M.	III Sh. Eg.
	10	27	P. M.	I Tr. In.
	11	18	"	I Sh. Eg.
3	12	39	A. M.	I Tr. Eg.
6	3	23	"	II Ec. Dis.
Aug. 8	12	06	A. M.	II Sh. Eg.
	12	21	"	II Tr. In.
	2	47	"	II Tr. Eg.
9	1	41	"	I Ec. Dis.
	3	49	"	III Sh. In.
	9	45	P. M.	II Oc. Re.
	10	58	"	I Sh. In.
10	12	19	A. M.	I Tr. In.
	1	12	"	I Sh. Eg.
	2	31	"	I Tr. Eg.
	11	39	P. M.	I Oc. Re.
12	11	21	"	III Oc. Dis.
13	12	54	A. M.	III Oc. Re.
15	12	12	"	II Sh. In.
	2	43	"	II Sh. Eg.
	2	52	"	II Tr. In.
16	3	35	"	I Ec. Dis.
	9	41	P. M.	II Ec. Re.
	9	47	"	II Oc. Dis.
17	12	12	A. M.	II Oc. Re.
	12	52	"	I Sh. In.
	2	09	"	I Tr. In.
	3	05	"	I Sh. Eg.
	10	03	P. M.	I Ec. Dis.
18	9	34	"	I Sh. Eg.
	10	48	"	I Tr. Eg.
19	9	50	"	III Ec. Dis.
	11	50	"	III Ec. Re.
20	3	07	A. M.	III Oc. Dis.
22	2	49	"	II Sh. In.
23	9	50	P. M.	II Ec. Dis.
24	2	37	A. M.	II Oc. Re.
	2	46	"	I Sh. In.
	3	58	"	I Tr. In.
	11	58	P. M.	I Ec. Dis.
25	3	18	A. M.	I Oc. Re.
	8	58	P. M.	II Tr. Eg.
	9	14	"	I Sh. In.
	10	25	"	I Tr. In.
	11	28	"	I Sh. Eg.
26	12	37	A. M.	I Tr. Eg.
	9	46	P. M.	I Oc. Re.
27	1	51	A. M.	III Ec. Dis.
	3	50	"	III Ec. Re.
30	8	44	P. M.	III Tr. In.
	10	08	"	III Tr. Eg.
31	12	25	A. M.	II Ec. Dis.

VARIABLE STARS.

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
July	1- 5	14	July	22-28	17	Aug.	5-12	19	Aug.	21-28	21
	6-13	15		28-35	18		13-20	20		29-36	22
	14-21	16									

Minima of Variable Stars of the Algol Type.

[Alternate minima only are given for the Algol variables, this month].

U Cephei.

	d	h
July	5	18
	10	17
	15	17
	20	17
	25	16
	30	16
Aug.	4	16
	9	15
	14	15
	19	15
	24	14
	29	14

Z Persei.

	d	h
July	4	21
	11	0
	17	2
	23	5
	29	8
Aug.	4	10
	10	13
	16	16
	22	19
	28	21

Algol.

	d	h
July	2	11
	8	5
	13	22
	19	16
	25	10
	31	3
Aug.	5	21
	11	14
	17	8
	23	2
	28	19

λ Tauri.

	d	h
July	2	10
	10	8
	18	5
	26	3
Aug.	3	1
	10	23
	18	21
	26	18

S Velorum.

	d	h
July	2	18
	14	15
	26	12
Aug.	7	9
	19	5
	31	2

W. Urs. Maj.

Period $4^h\ 0^m.1$

July 1-31 12^h

Aug. 1-31 13

RR Velorum.

	d	h
July	2	13
	6	6
	9	23
	13	16
	17	9
	21	2
	24	19
	28	12
Aug.	1	5
	4	22
	8	15
	12	8
	16	1
	19	18
	23	11
	27	4
	30	21

Z Draconis.

	d	h
July	1	9
	4	3
	6	19
	9	12
	12	5
	14	22
	17	16
	20	9
	23	2
	25	19
	28	12
	31	5
Aug.	2	22
	5	15
	8	9
	11	2
	13	19
	16	12
	19	5
	21	23
	24	16
	27	9
	30	2

δ Librae.

	d	h
June	1	22
	6	14
	11	6
	15	21
	20	13
	25	5
	29	20
Aug.	3	12
	8	4
	12	20
	17	11
	22	3
	26	19
	31	10

U Coronae.

	d	h
July	3	2
	10	0
	16	22
	23	20
	30	17
Aug.	6	15
	13	13
	20	10
	27	8

R Aræ.

	d	h
July	5	1
	13	21
	22	17
	31	14
Aug.	9	10
	18	7
	27	3

U Ophiuchi.

	d	h
July	1	1
	2	17
	4	9
	6	1
	7	18
	9	10
	11	2
	12	18
	14	11
	16	3
	17	19
	19	12
	21	4
	22	20
	24	12
	26	5
	27	21
	29	13
	31	5
Aug.	1	22
	3	14
	5	6
	6	22
	8	15
	10	7
	11	23
	13	15
	15	8
	17	0
	18	16
	20	8
	22	1
	23	17
	25	9
	27	1
	28	18
	30	10

Z Herculis.

	d	h
July	1	21
	3	18
	9	21
	11	18
	17	20
	19	17
	25	20
	27	17
Aug.	2	20
	4	16
	10	19
	12	16
	18	19
	20	16
	26	18
	28	15

RS Sagittarii.

	d	h
July	1	8
	6	4
	11	0
	15	20
	20	16
	25	12
	30	8
Aug.	4	4
	9	0
	13	20
	18	16
	23	12
	28	8

RX Herculis.

	d	h
July	1	11
	3	5
	5	0
	6	19
	8	13
	10	8
	12	3
	13	21
	15	16
	17	11
	19	5
	21	0
	22	19
	24	13
	26	8
	28	3
	29	21
	31	15
Aug.	2	11
	4	6
	6	0
	7	19
	9	14
	11	8
	13	3
	14	22

RX Herculis.

	d	h
Aug.	16	16
	18	11
	20	6
	22	0
	23	19
	25	14
	27	8
	29	3
	30	22

RV Lyræ.

	d	h
July	3	21
	11	2
	18	7
	25	11
Aug.	1	16
	8	21
	16	1
	23	6
	29	11

U Sagittæ.

	d	h
July	1	22
	8	16
	15	10
	22	5
	28	23
Aug.	4	17
	11	11
	18	6
	25	0
	31	18

SY Cygni.

	d	h
July	6	19
	18	19
	30	19
Aug.	11	20
	23	20

SW Cygni.

	d	h
July	4	12
	13	16
	22	19
	31	23
Aug.	10	2
	19	6
	28	9

UW Cygni.

	d	h
July	1	18
	8	16
	15	13
	22	11
	29	9
Aug.	5	6
	12	4
	19	2
	25	23

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini.

	d	h
July	2	17
	12	7
	21	22
	31	13
Aug.	10	3
	19	18
	29	9

VV Cygni.

	d	h
July	1	12
	4	11
	7	10
July	10	9
	13	8
	16	7
	19	6
	22	4
	25	3
	28	2
	31	1
Aug.	3	0
	5	23
	8	22
	11	21
Aug.	14	20
	17	19
	20	17
	23	16
	26	15
	29	14

VW Cygni.

	d	h
July	7	1
	23	22
Aug.	9	18
	26	15

Y Cygni.

	d	h
July	3	16
	5	1
	9	16
	11	1
	15	15
	17	0
	21	15
	23	0
	27	15
	29	0
Aug.	2	15
	4	0
Aug.	8	15
	10	0
	14	15
	16	0
	20	14
	21	23
	26	14
	27	23

UZ Cygni.

	d	h
July	20	19
Aug.	21	3

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h		d	h		d	h		d	h
July	2	2	July	17	19	Aug.	2	12	Aug.	18	5
	4	8		20	1		4	18		20	11
	6	14		22	7		7	0		22	16
	8	20		24	13		9	5		24	24
	11	2		26	18		11	11		27	4
	13	7		29	0		13	17		29	10
	15	13		31	6		15	23			

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
July	1	8	July	17	17	Aug.	1	0	Aug.	16	9
	3	9		19	18		3	1		18	10
	5	10		21	19		5	3		20	11
	7	11		23	20		7	4		22	12
	9	12		25	21		9	5		24	13
	11	13		27	22		10	6		26	14
	13	14		29	23		12	7		28	15
	15	16					14	8		30	16

RX (10.1903) Lyræ.—In A. N. 3943 Mr. W. Stratanow of Tachkent, Russia, gives the results of an examination of the impression of this star on 122 plates in the years 1895-1900. He finds a decided maximum indicated in July 1896 and another in October 1897. By combining the maximum on July 15, 1896, with that on April 21, 1903, he finds for the period 247 days. The magnitude at maximum is 12, while that at minimum is 16 or below.

Variable 86.1903 Tucanæ.—This star is reported by Dr. David Gill to be a long period variable, from 8.0 magnitude to invisible. Its position according to the CPD (Cape Photographic Durchmusterung) is

1875.0 R. A. $22^h\ 32^m\ 17^s.9$; Decl. $-62^\circ\ 12'.2$.

Variable Stars of Short Period not of the Algol Type.

	Minimum.			Maximum.		
		d	h		d	h
S Normae	July	1	11	July	5	21
T Velorum		1	16		3	1
δ Cephei		1	20		3	5
U Vulpeculae		2	0		4	3
V Velorum		2	3		3	2
X Sagittarii		2	20		5	17
V Carinae		2	23		5	3
U Aquilae		3	5		5	9
S Triang. Austr.		8	7		5	9
U Sagittarii		3	14		6	13
Y Ophiuchi		4	7		10	12
SU Cygni		4	15		5	23
S Crucis		4	22		6	10
S Sagittæ		5	10		8	20
S Muscae		5	10		8	21
RV Scorpii		5	12		6	22
Y Sagittarii		6	2		7	21
T Velorum		6	7		7	16
β Lyræ		6	12		9	14
V Velorum		6	12		7	11
R Crucis		6	15		8	0
W Sagittarii		6	15		9	15
T Crucis		6	21		8	22
δ Cephei		7	5		8	14
η Aquilæ		7	10		9	19
T Vulpeculae		7	20		9	5
TX Cygni		8	4		13	7
SU Cygni		8	11		9	19
κ Pavonis		8	18		12	13
S Crucis		9	14		11	2
V Carinae		9	15		11	19
S Trianguli Austr.		9	15		11	17
X Sagittarii		9	20		12	17
U Vulpeculae		9	23		12	2
U Aquilae		10	5		12	9
V Centauri		10	6		11	17
U Sagittarii		10	8		13	7
W Virginis		10	9		18	14
V Velorum		10	21		11	20
T Velorum		10	22		12	7
X Cygni		11	0		17	5
S Normae		11	5		15	15
RV Scorpii		11	13		12	23
Y Sagittarii		11	20		13	15
T Vulpeculae		12	6		13	15
SU Cygni		12	7		13	15
R Crucis		12	11		13	20
δ Cephei		12	14		13	23
β Lyræ		12	23		16	6
T Crucis		13	15		15	16
S Sagittæ		13	20		17	6
T Monocerotis		13	21		22	7
W Sagittarii		14	5		17	5
S Crucis		14	7		15	19
η Aquilae		14	14		16	23
S Muscae		15	2		18	13
V Velorum		15	6		16	5
T Velorum		15	14		16	23
V Centauri		15	18		17	5
S Triang. Austr.		15	23		18	1
SU Cygni		16	3		17	11
V Carinae	July	16	7	July	18	11
T Vulpeculae		16	17		18	2
X Sagittarii		16	21		19	18
U Sagittarii		17	2		20	1
U Aquilae		17	5		19	9
Y Sagittarii		17	15		19	10
RV Scorpii		17	15		19	1
κ Pavonis		17	20		21	15
δ Cephei		17	23		19	8
R Crucis		18	6		19	15
U Vulpeculae		18	10		20	13
S Crucis		18	23		20	11
β Lyræ		19	10		22	12
V Velorum		19	15		20	14
SU Cygni		20	0		21	8
T Velorum		20	5		21	14
T Crucis		20	8		22	9
S Normae		21	0		25	10
T Vulpeculae		21	3		22	12
V Centauri		21	5		22	16
Y Ophiuchi		21	10		27	15
η Aquilae		21	18		24	3
W Sagittarii		21	20		24	20
S Sagittae		22	5		25	15
S Triang. Austr.		22	7		24	9
TX Cygni		22	21		28	0
V Carinae		23	0		25	4
δ Cephei		23	7		24	16
Y Sagittarii		23	9		25	4
RV Scorpii		23	16		25	2
U Sagittarii		23	20		26	19
SU Cygni		23	20		25	4
X Sagittarii		23	21		26	18
V Velorum		24	0		24	23
R Crucis		24	2		25	11
U Aquilae		24	6		26	10
S Crucis		24	16		26	4
S Muscae		24	18		28	5
T Velorum		24	21		26	6
T Vulpeculae		25	14		26	23
β Lyrae		25	21		29	0
U Vulpeculae		25	23		28	2
V Centauri		26	17		28	4
κ Pavonis		26	22		30	17
T Crucis		27	3		29	4
X Cygni		27	9		33	14
W Virginis		27	16		35	21
SU Cygni		27	17		29	1
S Crucis		28	8		29	20
V Velorum		28	9		29	8
S Triang.Austr.		28	15		30	17
δ Cephei		28	18		30	3
η Aquilae		28	22		31	7
Y Sagittarii		29	4		30	23
W Sagittarii		29	10		32	10
T Velorum		29	12		30	21
V Carinae		29	16		31	20
RV Scorpii		29	18		31	4
R Crucis		29	22		31	7
T Vulpeculae		30	0		31	9
U Sagittarii		30	14	Aug.	2	13

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
S Sagittae	July 30	14	Aug. 3	0	W Virginis	Aug. 13	22	Aug. 22	3
S Normae	30	18	5	4	κ Pavonis	14	3	17	22
X Sagittarii	30	21	2	18	β Lyrae	14	6	17	8
U Aquilae	31	6	2	10	U Aquilae	14	7	16	11
SU Cygni	31	13	1	21	ζ Geminorum	14	14	19	14
V Centauri	Aug. 1	5	2	16	V Velorum	14	20	15	19
β Lyrae	1	8	4	10	Y Sagittarii	15	11	17	6
V Velorum	1	18	2	17	SU Cygni	15	22	17	6
S Crucis	2	1	3	13	W Geminorum	16	1	18	16
T Crucis	2	20	4	21	S Crucis	16	3	17	15
U Vulpeculae	2	23	5	2	T Crucis	16	7	18	8
δ Cephei	3	1	4	10	S Sagittae	16	8	19	18
T Velorum	3	3	4	12	R Crucis	16	9	17	18
S Muscae	3	10	6	21	S Triang. Austr.	16	14	18	16
T Vulpeculae	3	11	4	20	T Vulpeculae	16	18	18	3
Y Sagittarii	3	22	5	17	RV Scorpii	16	22	18	8
S Triang. Austr.	3	23	6	1	T Velorum	17	1	18	10
SU Cygni	4	9	5	17	V Centauri	17	17	19	4
R Crucis	4	18	6	3	V Carinae	18	19	20	23
RV Scorpii	4	19	6	5	U Vulpeculae	18	22	21	1
κ Pavonis	5	1	8	20	δ Cephei	19	4	20	13
η Aquilae	5	3	7	12	V Velorum	19	5	20	4
V Carinae	5	0	7	14	S Normae	19	6	23	16
W Sagittarii	6	0	9	0	η Aquilae	19	11	21	20
V Velorum	6	2	7	1	SU Cygni	19	19	21	3
U Sagittarii	6	8	9	7	U Sagittarii	19	20	22	19
TX Cygni	6	15	11	18	β Lyrae	20	17	24	0
V Centauri	6	17	8	4	S Crucis	20	20	22	8
S Crucis	6	17	8	5	X Sagittarii	20	22	23	19
X Sagittarii	6	21	9	18	W Sagittarii	21	4	24	4
U Aquilae	7	7	9	11	T Vulpeculae	21	5	26	14
Y Ophiuchi	7	13	13	18	Y Sagittarii	21	6	23	1
T Velorum	7	18	9	3	U Aquilae	21	8	23	12
β Lyrae	7	19	11	2	TX Cygni	21	9	26	12
T Vulpeculae	7	21	9	6	T Velorum	21	17	23	2
S Sagittae	7	23	11	9	R Crucis	22	5	23	14
SU Cygni	8	5	9	13	S Muscae	22	17	26	4
W Geminorum	8	8	10	23	S Triang. Austr.	22	22	25	0
δ Cephei	8	10	9	19	RV Scorpii	23	0	24	10
S Normae	9	12	13	22	T Crucis	23	1	25	2
T Crucis	9	14	11	15	V Centauri	23	4	24	15
Y Sagittarii	9	17	11	12	κ Pavonis	23	5	27	0
T Monocerotis	9	22	17	20	V Velorum	23	14	24	13
S Triang. Austr.	10	7	12	9	SU Cygni	23	15	24	23
V Velorum	10	11	11	10	W Geminorum	23	19	26	10
R Crucis	10	13	11	22	δ Cephei	24	12	25	21
RV Scorpii	10	21	12	7	Y Ophiuchi	24	15	30	20
U Vulpeculae	10	22	13	1	S Sagittae	24	17	28	3
S Crucis	11	10	12	22	ζ Geminorum	24	18	29	18
SU Cygni	12	2	13	10	V Carinae	25	11	27	15
V Carinae	12	2	14	6	S Crucis	25	12	27	0
V Centauri	12	5	13	16	T Vulpeculae	25	15	27	0
η Aquilae	12	7	14	16	T Velorum	26	8	27	17
T Vulpeculae	12	8	13	17	U Sagittarii	26	13	29	12
T Velorum	12	10	13	19	η Aquilae	26	15	28	23
X Cygni	12	19	19	0	U Vulpeculae	26	21	29	0
S Muscae	13	1	16	12	Y Sagittarii	27	0	28	19
U Sagittarii	13	2	16	1	β Lyrae	27	4	30	6
W Sagittarii	13	14	16	14	SU Cygni	27	11	28	19
δ Cephei	13	19	15	4	X Sagittarii	27	22	30	19
X Sagittarii	13	21	16	18	R Crucis	28	1	29	10

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
U Aquilae	Aug. 28	8	Aug. 30	12	T Crucis	Aug. 29	18	Aug. 31	19
V Centauri	28	16	30	3	δ Cephei	29	21	31	6
W Sagittarii	28	19	31	19	T Vulpeculae	30	2	31	11
V Velorum	28	23	29	22	S Crucis	30	5	31	17
S Normae	29	0	33	10	T Velorum	30	23	32	8
RV Scorpii	29	1	30	11	W Virginis	31	5	39	10
X Cygni	29	4	35	9	SU Cygni	31	7	32	15
S Triang. Austr.	29	6	31	8					

Approximate Magnitudes of Variable Stars May 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	s	R Camel.	14	25.1	+84	17	9.5i
T Cassiop.	0	17.8	+55	14	10.0d	R Bootis	14	32.8	+27	10	7.5d
R Androm.	0	18.8	+38	1	8d	S Librae	15	15.6	−20	2	8.5i
S Ceti	0	19.0	− 9	53	s	S Serpentis	15	17.0	+14	40	12i
S Cassiop.	1	12.3	+72	5	14f	S Coronae	15	17.3	+31	44	8.5d
R Piscium	1	25.5	+ 2	22	s	S Urs. Min.	15	33.4	+78	58	11d
R Trianguli	1	31.0	+33	50	12d	R Coronae	15	44.4	+28	28	6
U Persei	1	52.9	+54	20	12d	V "	15	45.9	+39	52	8.5
R Arietis	2	10.4	+24	36	s	R Serpentis	15	46.1	+15	26	11i
o Ceti	2	14.3	− 3	26	s	R Herculis	16	1.7	+18	38	13d
S Persei	2	15.7	+58	8	11	R Scorpii	16	11.7	−22	42	13d
R Ceti	2	20.9	− 0	38	s	S "	16	11.7	−22	39	11i
U "	2	28.9	−13	35	s	U Herculis	16	21.4	+19	7	9d
R Persei	3	23.7	+35	20	9	W Herculis	16	31.7	+37	32	12.5d
R Tauri	4	22.8	+ 9	56	s	R Draconis	16	32.4	+66	58	11.3d
S "	4	23.7	+ 9	44	s	S Herculis	16	47.4	+15	7	12f
R Aurigæ	5	9.2	+53	28	8.7d	R Ophiuchi	17	2.0	−15	58	f
U Orionis	5	49.9	+20	10	6.4	T Herculis	18	5.3	+31	0	7.5i
R Lyncis	6	53.0	+55	28	14f	R Scuti	18	42.2	− 5	49	5i
R Gemin.	7	1.3	+22	52	13.7d	R Aquilae	19	1.6	+ 8	5	7i
S Canis Min.	7	27.3	+ 8	32	9.8d	R Sagittarii	19	10.8	−19	29	f
R Cancri	8	11.0	+12	2	11d	S "	19	13.6	−19	12	f
V "	8	16.0	+17	36	9.0d	R Cygni	19	34.1	+49	58	13d
S Hydrae	8	48.4	+ 3	27	12.0d	RT "	19	40.8	+48	32	8i
T "	8	50.8	− 8	46	10.4d	X "	19	46.7	+32	40	12d
R Leo. Min.	9	39.6	+34	58	12.5d	S Cygni	20	3.4	+57	42	f
R Leonis	9	42.2	+11	54	7.0i	RS "	20	9.8	+38	28	9.3
R Urs. Maj.	10	37.6	+69	18	11i	R Delphini	20	10.1	+ 8	47	f
R Comae	11	59.1	+19	20	f	U Cygni	20	16.5	+47	35	8
T Virginis	12	9.5	− 5	29	12.3d	V "	20	38.1	+47	47	11d
R Corvi	12	14.4	−18	42	11.5d	T Aquarii	20	44.7	− 5	31	f
Y Virginis	12	28.7	− 3	52	f	R Vulpec.	20	59.9	+23	26	8
T Urs. Maj.	12	31.8	+60	2	9i	T Cephei	21	8.2	+68	5	7d
R Virginis	12	33.4	+ 7	32	10.7	S "	21	36.5	+78	10	8
S Urs. Maj.	12	39.6	+61	38	8.3i	S Lacertae	22	24.6	+39	48	s
U Virginis	12	46.0	+ 6	6	9.0i	R "	22	38.8	+41	51	s
V "	13	22.6	− 2	39	f	S Aquarii	22	51.8	−20	53	s
R Hydrae	13	24.2	−22	46	5.7d	R Pegasi	23	1.6	+10	0	s
S Virginis	13	27.8	− 6	41	12	S "	23	15.5	+ 8	22	s
R Can. Ven.	13	44.6	+40	2	9	R Aquarii	23	38.6	−15	50	s
S Bootis	14	19.5	+54	16	13d	R Cassiop.	23	53.3	+50	50	9d

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

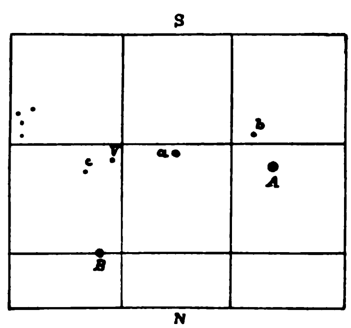
Derived from observations made at the Halsted, McCormick, Vassar College and Harvard Observatories.

The Suspected Variable 9.1904 Orionis.—This star, which was noted in the May number of POPULAR ASTRONOMY, was observed here as a comparison star of 2100 U Orionis on fourteen dates from 1903 September 18, to 1904 March 4, with Pickering's equalizing wedge photometer attached to the 58.4 cm. refractor. Two observations were made by Professor W. M. Reed; the rest were made by the writer. At each observation the star was compared with Hagen 21 (BD. + 20°1179). The observed difference between the two stars ranged from $0^m.28$ to $1^m.02$, indicating a variation of $0^m.74$. These observations do not agree with the period given by Luther. A number of other periods were tried, but none was found that would fit the observations.

PRINCETON UNIVERSITY, ZACCHEUS DANIEL.
PRINCETON, N. J., 1904 May 18.

New Variable 15.1904 Geminorum.—This is announced by Mr. K. Bohlin, of Stockholm, in A. N. 3944. It is a 12th magnitude star near the 5th magnitude star east of δ Geminorum. The accompanying chart shows the stars in its vicinity. Mr. Bohlin gives the following list of comparison stars:

	No.	Mag.	R. A. 1900.0 h	m	s	Decl. 1900.0 °	′
A	2953	5.5	7	21	48	+ 21	39.1
b		10					
a	2948	9.1	7	21	19	+ 21	37.7
B	2945	6.4	7	20	56	+ 21	44.2
c		13					



VICINITY OF THE VARIABLE STAR
15.1904 GEMINORUM.

The time of variation at minimum is apparently less than 28 days, while the total period may be 338 days, or possibly 169 days, but probably not less than 169 days. The next minimum is predicted for Dec. 24, 1904.

New Variable 16.1904 Persei.—This is in the great cluster χ Persei and was found by Mme. L. Ceraski on the photographic plates taken by M. S. Blajko at Moscow. It is No. 111 on Vogel's chart and No. 120 on Pihl's chart of the cluster. The BD. gives this star as 8.6^m, Vogel, 8.5-8.6, Pihl, 8.5 and Berlin A. G. C. 8.5. On April 1 and 2, 1904 Mr. Blajko saw it as 10.0^m. The position of the star for 1900.0 is

$$\text{R. A. } 2^h\ 15^m\ 20^s.36;\ \text{Decl.} + 56^\circ\ 39'\ 06''.1$$

The period and character of its light changes is unknown.

New Variable 17.1904 Andromedæ.—In A. N. 3944 Mr. A. Stanley Williams calls attention to this star and gives its period as 182 days and the range of variation as nearly two magnitudes (8½-10½). The star is BD. + 48°616 and its position for 1855 is

R. A. $2^h\ 01^m\ 41^s$; Decl. + 48° 14′.7

Future minima should occur on July 29, 1904, and Jan. 27, 1905, and a maximum probably about Oct. 28 next.

New Variable Star 18.1904 Ophiuchi.—A new variable BD. + 9°.3414 has been found by Mme. L. Ceraski on the photographs taken at Moscow. The position for 1900 is

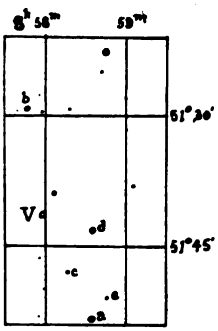
R. A. $17^h\ 28^m\ 27^s.6$; Decl. + 9° 29′.9.

The variation appears to be between 9.0 and 12, but the period is unknown.

New Variable Star 19.1904 Leonis Minoris.—Mr. T. D. Anderson announces, in A. N. 3946, a star which is not included in the BD. whose approximate place for 1855.0 is

R. A. $9^h\ 45^m\ 4^s$; Decl. + 35° 36′.5.

It is at present slowly but steadily decreasing, having changed from 8.4 Mar. 10 to 8.9 Apr. 30. These estimates have been made on the assumption that the neighboring stars BD. + 35°2077 and 2078 are 8.3^m and 9.1^m respectively.



VICINITY OF V URS. MAJ.

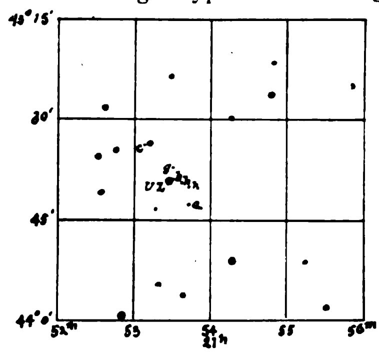
The Light Changes of the Variable V Ursæ Maj.—In A. N. 3941 Dr. K. Graff, of Hamburg, gives the results of a series of observations of this star extending from March 24, 1902 to Oct. 7, 1903. He finds the period to be 201.5 days, the star remaining constant at $9^m.6$ for 98 days, then falling slowly to a minimum at $10^m.6$ and slowly rising again. It thus appears to be an Algol type variable of exceptionally long period. The following provisional elements are given:

Minimum = 1903 April 26 (J. D. 2416231) + $201^d.5$ E.

The accompanying chart shows the stars in the vicinity of the variable. The positions of the brighter stars are:

	R. A. h	m	s	Decl. °	′	Mag.	°
—	8	58	45	+ 51	22.6	8.0	DM. + 51.1485
a	8	58	35	51	53.4	9.20	DM. 51.1484
b	8	57	45	51	29.0	9.75	DM. + 51.1483
c	8	58	16	51	48.0	10.50	
d	8	58	36	51	43.2	9.90	
e	8	58	46	+ 51	51.0	10.40	

UZ Cygni.—Dr. Hartwig in A. N. 3944 announces an observation of a secondary minimum of this star, midway between the ordinary minima. This star has been regarded as of the Algol type with the long period of 31.4 days.



VICINITY OF UZ CYGNI.

The principal minimum occupies about 60 hours, while the secondary lasts only about 8 hours. The accompanying chart gives the relative positions of the variable and the neighboring stars.

GENERAL NOTES.

Mountain Station for Goodsell Observers.—As will be noticed elsewhere in this issue, a preliminary statement regarding astronomical work for the months of July and August has been made. Some years ago we visited the Rocky mountains in the summer for the purpose of learning something of the advantages of elevations there for observing purposes. It was then learned that some localities visited gave promise, in a preliminary way, of that which was wanted for certain kinds of astronomical work that need to be done.

These places were situated near the Great Northern Railway in the Rocky mountains in the vicinity of the summit of the range. The general altitude below the more abrupt columnar elevations or peaks of the range is about 5,000 feet above the level of the sea. Wide areas with elevation but a little less are found in this neighborhood within a circuit of ten or fifteen miles. If other conditions needed are found thereabout, favorable summer observations may be made in the line desired. It is the present intention of the Director of Goodsell Observatory to make further trial, to know if this altitude, which is easily accessible, is really good enough in other respects for the kind of work which we are planning for, and hoping to do somewhere.

We have been greatly encouraged by thoughtful, able and interested friends who have provided the expenses for this expedition without certain knowledge on the part of any one that it will be a success.

Columbia University Observatory.—Dr. Harold Jacoby has been promoted to a professorship in astronomy at Columbia University. Professor J. K. Rees, the Director of the Observatory, has his leave of absence continued until July 1905. Professor Jacoby will remain acting Director during Professor Rees' absence. Dr. Charles L. Poor of Johns Hopkins University has been appointed Professor of Astronomy and he will be associated with Professor Jacoby.

The Swasey Depression Range Finder.—Messrs. Warner and Swasey of Cleveland, Ohio, have recently been interested in bringing out an instrument called The Swasey Depression Range Finder. Its purpose is indicated in its name. To make it as complete and as efficient as possible, allowance must be made for variable refraction, height of tide at the position of the object, the range of which is being found and the curvature of the Earth.

The accuracy that the makers have reached is an error which comes within one-half of one per cent, on the longest range, and in many instances, the error does not exceed one quarter of one per cent. The important thing about this new instrument is the small error in range that is last noted above. On this account the Government has become interested in this useful instrument and has already purchased for its own use a hundred or more of them. The tests already made by government officers prove very satisfactory.

We have seen a detailed description of the instrument, and it is of such general interest that we will soon publish it with illustrations to aid the general reader in understanding what it is for and how it works.

The Fifth Satellite of Jupiter.—Number 51 of the Lick Observatory Bulletin consists chiefly of the observations of the fifth satellite of Jupiter in 1903 by R. G. Aitken. One feature of these observations is especially noteworthy. He says: "From the observing notes given with each night's measures it will be noticed that the Fifth satellite was very easily seen this year. It was so bright that on one or two nights I was in doubt for a time as to whether the object seen might not be a small star, and I am satisfied that a 14th magnitude star within 25″ of the planet's limb would appear fainter than the satellite did."

New Glass for Lenses.—The fine qualities of glass made at Jena have revolutionized the construction of lenses, especially for strong visual or photographic work. It is claimed by those who are expert in such things that combinations of certain kinds of glass can now be made which have been heretofore regarded as impossible, and that from these new combinations some properties are secured that are full of promise. Those but little acquainted with the art of glass-making will easily remember that it is only a few years ago that the really scientific method for the production of specific kinds of glass was brought to such a degree of perfection at Jena, that the lenses for microscopes were so greatly improved that work with that important instrument was given a fresh impulse everywhere. The great reputation of the Jena manufacturers was made almost in a day.

Astronomers then began to look into the matter. At first they were a little skeptical, although the specimens examined were almost perfectly clear, colorless and remarkably light of weight. The source of uncertainty for the astronomer lay in the direction of the hygrometric qualities of some of the early specimens. The fear was that the glass would not be durable. Its qualities would deteriorate. If this should prove true, it would never do for large astronomical lenses. At first, on this account, only small lenses for telescopes were made for trial. As far as we know, the fear of the astronomer has not been realized. Large glasses are now made of the Jena product and it stands the severest test, both of varying temperature and of moisture and deteriorating for a period of eighteen years, at least. The important change that has come from the new process of glass-

making is the fact that a purchaser can now leave an order for a specific kind of glass whose properties are specified to the last detail, and the manufacturer takes that order into his laboratory and makes the glass according to the order, as a druggist would fill the prescription of a physician.

The optician will then make a prism from a piece of the glass so manufactured, and examine its work by the aid of the spectroscope to see if the glass chemist has done his work well, and also to see if the constants obtained are such as the mathematician wants for his curves for the telescope objective that he has promised to construct for some physicist anxious to do critical work of some kind in his investigations.

From such a chain of circumstances as this it does not require very great insight or scientific knowledge to show how important the improvement in the quality of glass may be in carrying forward any one of a dozen different lines of physical research.

Notice of an interesting paper pertaining to this matter has just come to hand in the British Journal of Photography, which was read recently before the Royal Society of London, from which we take the following extract:

"The authors of the paper have made a number of measurements of the optical constants of the new material, which possesses great uniformity of composition, combined with transparency to ultra-violet radiations, while, unlike quartz, it is not doubly refracting. To test the homogeneity and, consequently, perfection of refracting power of the new medium, four slabs of it were prepared, cemented together, and from the mass a prism cut and polished. Any variation of density on any one of the slabs would have so affected the refraction as to render the prism useless as an instrument of precision; but so far was this from being the case that when tested against a similar prism of boro-silicate glass from Jena, all the slabs being from the same melting, the silica prism was found to be distinctly superior. A thin doublet had been made and was described; it had the vitreous silica for one component and fluorite for the other; the focal length of the combination is almost independent of the wave-length, in other words, the achromatism was almost perfect."

Brilliant Meteor.—An exceedingly brilliant meteor was seen from this place last Saturday evening, May 14, at $9^h\ 55^m$ central standard time. It fell from the direction δ Herculis towards the Earth on a straight line inclined 20° from the perpendicular towards the north. It was twenty minutes of arc in diameter, and allowing for irradiation probably it must have been at least fifteen minutes. It was of dazzling white, nearly round, very nearly pear shaped, but it left no train. It lasted a second and a half and disappeared two degrees above the horizon. I could not estimate its distance, but thought it to be 50 or 60 miles away, possibly much more. It appeared first at a height of 23°. It illuminated the atmosphere and eastern horizon very brightly while it lasted.

CHATTANOOGA, Tenn., H. L. SMITH.
May 16, 1904.

Precession and Assyriological Discoveries.—Mr. Maunder at the April meeting of the Royal Astronomical Society made some interesting statements about precession as it appears in books and articles dealing with Assyriological discoveries. He said the paper which he had to submit to the Meeting was in rather strong contrast to those which they had been considering, for in-

stead of dealing with the most recent advances in theory and observation, it went back to the astronomy of 4000 or 5000 years ago. Mrs. Maunder and he had been led to write the paper from noticing the very loose way in which the effect of precession was referred to in books and articles dealing with Assyriological discoveries. Thus 2500 B. C. was often given as the date when the Sun at the spring equinox ceased to be in Taurus, and was recognized as in Aries. It had even been stated that the Sun was at the First Point of Aries at the spring equinox in 2540 B. C., whereas it had that position only about 150 B. C. Of course these dates assumed that the ancient Accadians and Assyrians considered the Sun as amongst the stars with which it was in conjunction. But it was possible that they associated the Sun with the stars with which it was in opposition, or by means either of the heliacal risings or settings of the stars. None of these four methods appears to have been the primitive one. But a fifth was in use at a very early age. It consisted in watching the position of the new Moon when first seen at the beginning of the year relative to a certain bright star. This star seems to have been Capella. It followed that the beginning of the second month was similarly marked by the seleniacal setting of Castor and Pollux. So long as this method was in use Taurus must have been the constellation associated with the first month of the year, and Gemini with the second. In accordance with this relation the signs for the patron deities of the first two months were a crescent moon "on its back" for the first month, and a pair of stars, for Istar and Tammuz, the "Heavenly Twins," for the second. The crescent Moon is of course more completely "on its back" when setting at the spring equinox than at any other time of the year. (Mr. Maunder showed some slides of boundary stones, dedicatory tablets, and signets, showing the three symbols alluded to).

Mr. Maunder continued that the second period of ancient astronomy, when Aries was taken as the first sign of the zodiac, probably arose during the period of great intellectual activity in Assyria associated with the reign of Assur-banipal. Hamal, the chief star of Aries, was in conjunction with the Sun at the spring equinox B. C. 700, and the equinox was observed directly by means of some mechanical method for determining time. The planets were observed in this age, and the various statements made about the god Marduk as the planet Jupiter showed that the value of that planet had been recognized as a means of determining the point of the sky in opposition to the Sun, and that the motion of that planet through a twelfth part of the ecliptic in the course of a year, and its division of that arc into three equal parts by its retrogression through 10 degrees, had also been noted.—*The Observatory*, April, 1904.

Lack of Transparency of Earth's Atmosphere.—The following circular letter was not received until May 3. This is the reason why notice of it appears late:

"You may have noticed that records have been published by Messrs. C. Dufour of Lausanne; H. H. Kimball, S. P. Langley, and C. G. Abbot of Washington; Max Wolf of Heidelberg; and Gorczynski of Warsaw; showing that an appreciable general diminution of the transparency of the Earth's atmosphere took place some time during the year 1902, but disappeared at some time during 1903. This is an important matter and may possibly be made the basis of an explanation of other meteorological phenomena. I beg to ask whether you have any records that will assist in defining the dates of beginning and ending, and

the extent of this change in transparency. Such records may consist of photometric or photographic observations of the brightness of the stars; changes in the solar or stellar spectra; unusual prevalence of halos, large Bishop's ring, or haze; observations of heat received from the Sun, as made with actinometers or pyrheliometers; observations of the polarization of the blue sky light and of scintillation of the stars.

"Undoubtedly this diminution and increase of transparency began and ended at different dates in different places, as the phenomena spread gradually over the world during the years 1902 and 1903; additional records are therefore desired in order to trace its progress. Will you not kindly examine your records from this point of view and send me the result for publication in a general article on this subject? CLEVELAND ABBE, Professor and Editor."

U. S. DEPT. OF AGRICULTURE, WEATHER BUREAU, April 15, 1904.
WASHINGTON, D. C.

New Determination of the Axis of Rotation of Mars by Percival Lowell.—In Bulletin No. 9 from Lowell Observatoty is found a full paper by Percival Lowell on a new determination of the position of the axis of rotation of the planet Mars. We give the results of this interesting piece of astronomical work.

At the conclusion of this paper Mr. Lowell says:

"Deductions of the position of the true pole of the planet from various such combinations follow. First comes that from the observations of 1901 and of 1903 complete; next that from those of 1901 and 1903 expurgated; third, that from the measures of 1903 before and after opposition, complete; and fourth, that from the same expurgated. After which follow results from Schiaparelli's measures of 1882, 1884 and 1886, combined in pairs.

	Martian Pole.		Intersection of Martian Equator and Ecliptic.		Tilt of Martian Equator to Martian Ecliptic.
LOWELL— Epoch 1903.	R. A. ° ′	Decl. ° ′	R. A. ° ′	Decl. ° ′	° ′
1901 and 1903—*Unexpurgated*	314 56.2	55 16.2	86 7.3	24 32.1	22 23.0
1901 and 1903—*Expurgated*...	315 7.0	55 2.3	85 50.9	24 31.3	22 37.0
1903—Before and after opposition—*Unexpurgated*	316 47.1	54 31.1	86 39.8	24 33.6	23 40.2
1903—Before and after opposition—*Expurgated*..................	315 56.8	54 39.4	86 0.4	24 31.8	23 13.5
SCHIAPARELLI— Epoch 1903.					
III 1882 and IV 1884...............	319 56.5	54 35.6	90 13.0	24 39.2	24 56.0
III 1882 and V 1886................	321 0.2	55 11.2	92 25.9	24 41.8	24 58.0
IV 1884 and V 1886.................	320 26.7	55 52.8	93 13.0	24 42.5	24 16.0
STRUVE—					
Results—Epoch 1903................	317 16.2	5[illegible] 38.4	83 43.7	24 24.2	25 12.8

It will be seen how little relative effect the correction for possible error in tilting the eyes occasioned, less than that between the two oppositions considered together and apart; but that it did result in bringing the two results nearer together. It will also be noticed that Schiaparelli's determinations show about the same divergence *inter se* as those of 1901 and 1903. Struve's result differs from both.

From these observations of 1901 and 1903 I conclude, therefore, that the position of the pole of Mars lies midway between the expurgated comparison of 1901 with 1903, and of 1903 before and after opposition, or about as follows:

	R. A. °	′	Decl. °	′
Position upon the Earth's Equator	315	32	54	51
Intersection of Martian Equator and Martian Ecliptic.	85	56	24	32
Inclination of Martian Equator to Ecliptic			22	55"

Watson's Twenty-two Asteroids.—At the death of Professor James C. Watson, which occurred in 1880, he left a sum of money, as an endowment fund, the income from which should be used to pay for the necessary computations to keep track of his asteroid famiy that none of them should be lost to the scientific world. It is now twenty-four years since this fund was provided and put into the hands of three trustees, who were Professor Simon Newcomb, chairman, Professor Lewis Boss and Professor W. L. Elkin. The plan adopted by the trustees, so far as we know, has been to make tables for these individual asteroids by which their places might be found for fifty years in advance. Up to three years ago when the work was undertaken by the Astronomical Department of the University of California, considerable had been done, but little was ready for publication. There are probably some good reasons why this work has been delayed so long. As a consequence, apparently, Aethra, one of the twenty-two is lost. Its path passes very near to that of Mars, and of course that asteroid would suffer in consequence violent perturbations, and its orbit has been probably greatly changed, for diligent search for it has not been successful up to the present time. In consequence of this lapse special investigation will be necessary to recover the lost child of this family. From a recent number of the Publications of the Astronomical Society of the Pacific (No. 95) it is learned that Miss Hobe will undertake this work. From the same source it is also learned that the entire direction of looking after and caring for this group of asteroids has been turned over to Professor Leuschner of the University of California.

During the last three years the perturbations of ten asteroids have been computed at Berkeley, those of two more are nearing completion and five others are under way. "The four remaining ones have been investigated by other astronomers in Europe ard America." Evidently this important piece of work is in good hands and it will be pushed to completion in less than twenty years.

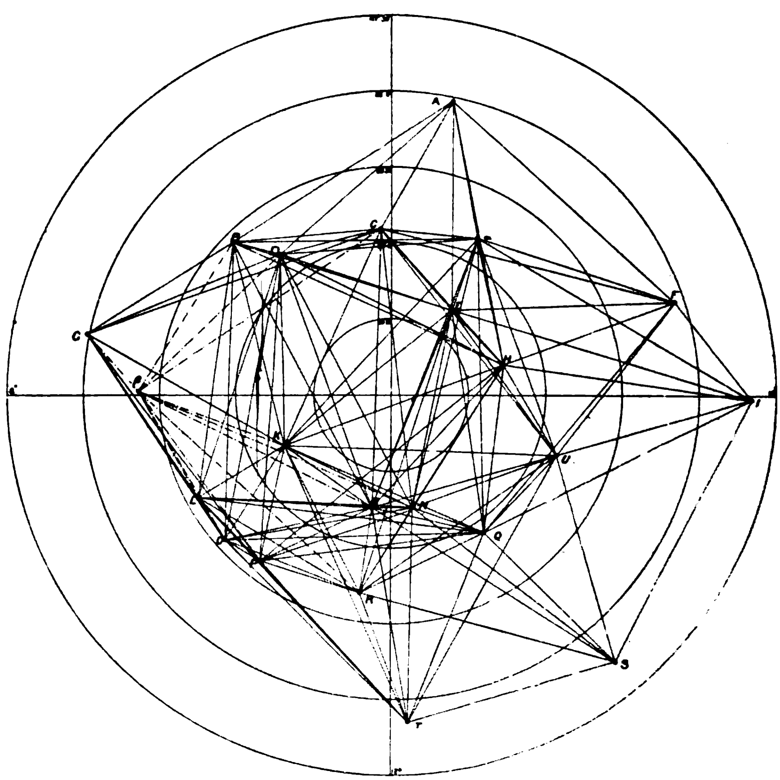
Heliometer Triangulation of the Circumpolar Region.—We have received part one of the Annals of the Cape Observatory, Vol. XI, on Southern polar researches, the principal part of which pertains to the heliometer triangulation of the southern circumpolar area. This work was done by S. S. Hough, chief assistant of the Royal Observatory, under the direction of Sir David Gill.

This paper is intended as the first of a series of memoirs to be devoted to the discussion of all accurate data pertaining to the positions of the stars surrounding the South Pole of the Heavens. The Poles of the celestial sphere are fundamental points in sidereal astronomy, and accurate knowledge of their positions is of course, of the greatest importance. Determinations of these points have been made usually from a knowledge of the positions of circumpolar stars. But the places of such stars have not been determined generally with sufficient ac-

curacy to give the position of the Pole, as exactly as it ought to be known for the real needs of modern astronomical work usually made to depend upon the assumed or predetermined place of this reference point. It is also true that there is no bright star near the South Pole which can be observed in daylight, so that work must be largely confined to the winter months on such circumpolars as are available near sunset and sunrise times.

Under such circumstances the heliometer triangulation of stars extending to rather more than 2° from the Pole has been carried forward to completion. It is planned that further memoirs will be made, and that they will deal with (1), the discussion of a series of photographic plates covering the circumpolar area; (2), a series of fundamental determinations made with the new Cape Meridian Circle; (3), the final adjustment and combination of all existing material suitable for the purpose.

The accompanying figure shows how the triangulation was planned and the extent to which it was carried out. The writer of the paper speaks of the precision of the results obtained as considerable although somewhat disappointing,



TRIANGULATION OF SOUTHERN CIRCUMPOLAR STARS.

as compared with others previously secured by the aid of the Cape Heliometer. He accounts for this from two circumstances. One is "the comparatively low altitude at which the observations were necessarily made, and the other the fact, that in the early stages the observers were largely inexperienced at refined astro-

nomical work of this character, and at the later stages, the instrument itself had developed defects due to wear, which may have materially influenced the precision attainable with it."

The work of chapter twelve which was done after the instrument had been thoroughly overhauled was independently reduced, and it shows improvement in the results in both directions.

Determination of the Relative Masses of 70 Ophiuchi.—In A. N. 3946 Mr. Adalbert Prey of Vienna gives the results of an investigation of the ratio of masses of the components of the binary star 70 Ophiuchi, using 33 meridian observations of the principal component. He obtains the remarkable result that the center of gravity of the system is four-fifths of the way from the principal component to the companion, so that the mass of the companion must be four times as great as that of the brighter star. Using Schur's parallax 0″.16, he finds the masses of the two stars to be 0.32 and 1.28 times the Sun's mass. Mr. Prey wishes to carry this investigation further and requests all observers who have unpublished observations of this star to communicate them to him.

The Telescope.—In D. Van Nostrand Company's Scientific Series, No. 51 has for its title, The Telescope, and the first edition of that book was prepared in 1879 by Thomas Nolan. The conditions under which that very useful little book was published were unknown to us until very recently. They are worth repeating, because they show the origin of the book and the opinion of some able astronomers concerning its real worth. The first edition was an 18 mo. volume in boards of 75 pages, which was the first half of a dissertation, written in part fulfillment of the requirements in competing for the John F. Stoddard one-hundred-dollar gold medal awarded by the University of Rochester, N. Y. At the suggestion of one of the examining committee, Professor William A. Rogers, at that time at Harvard University, the dissertation was published, first in Van Nostrand's Magazine, and afterwards reprinted in book form which sold at 50 cents.

During the year 1904, a second edition of this book has been published by the Van Nostrand Company, of New York, in revised and enlarged form. An entirely new chapter on the evolution of the modern telescope and a bibliography up to date has been added. It is of the same form as the first edition, containing 118 pages and sells at 50 cents.

Any one desiring knowledge of the optical principles involved in the construction of refracting and reflecting telescopes, will find this little handy volume worth many times its cost to them.

λ Andromedæ.—In *The Observatory* for May 1904 Mr. J. E. Gore calls the attention of astronomers engaged in the determination of stellar parallax to the case of the spectroscopic binary λ Andromedæ, discovered as a binary by Campbell in 1899. The period is about 19.2 days and the orbital velocity 5.6 miles a second, the companion being a dark body. From various considerations Mr. Gore estimates the mass of the system to be not more than 1/10 the mass of the Sun, and therefore, since the star is of the fourth magnitude, that it must

be comparatively near the Sun. He estimates that the parallax may be as large as 0″.34, so that an effort should be made to measure it. The star has a proper motion, according to the Greenwich 10-year Catalogue, of $0^s.0157$ in R. A. and 0″.425 in declination.

Radial Velocities of Twenty Stars by Frost and Adams.—This paper is another of the so-called decennial publications of Chicago University that have recently appeared, and some of which have received full notice in this journal in recent months past. The full title of the paper is, "Radial Velocities of Twenty Stars having Spectra of the Orion Type." The paper was prepared by Edwin B. Frost and Walter S. Adams of Yerkes Observatory, Williams Bay, Wisconsin. It begins with a brief reference to the history of the determination of the velocity of a star in the line of sight according to the Doppler-Fizeau principle, first attempted by Huggins in 1868, and by Vogel a little later, both of whom established the principle, as a method of investigation which has since been applied by many others to the study of the motions of nearly all celestial bodies.

The next step in advance noticed, was due to Campbell of Lick Observatory, who has done important work with the Mills spectrograph, an instrument of his own design, and the three things mentioned which give his work preëminence are, the use of iron as a comparison spectrum, the close attention to the optical and mechanical construction of the spectrograph and the refinement in the measurement of his photographic plates. On account of this three fold advantage the unit of measure has been changed from the German mile used by Vogel to the kilometer, a value only about one-seventh as great as that formerly employed.

The next point of interest in improving the spectrograph was to make it rigid to prevent flexure, and to maintain a constant temperature for the prisms while in use. From this paper it would appear that special attention was given to these things in the construction of the Bruce spectrograph of the Yerkes Observatory which was completed in the autumn of 1901, and which has been used in the observations that are the basis of this paper.

The work done is the most important part of all, and the choice of stars of the Orion type is of special interest because some physicists think that this class of stars occupy a position very early in the scale of stellar evolution. This is evidently the view of the authors of this paper. We think it is too much to say that there is general agreement of astronomers on this point. "The chemical constitution of these stars is simple, the chief elements showing lines of hydrogen, helium, oxygen, silicon, nitrogen and magnesium. The presence of helium is the principal characteristic of the type, whence they are frequently called helium stars."

The first point of difficulty met in the study of the radial velocity of these stars is the broad and diffuse nature of most of the lines of these spectra. Exact measurement is very difficult. Then, if the spectroscopist has an instrument of high dispersion like that of the Bruce spectrograph the difficulty of precision in measurement is increased. On this point the authors have given tests of the accuracy of their work that leaves no doubt in the mind of the critical reader of this paper, regarding the degree of accuracy reached in observation, measurement and reduction. They also speak of the optical features of the Bruce spectrograph, indicating that they were especially planned to cover a region of the spec-

trum, not naturally included by most of the large spectrographs engaged in radial work, and therefore centering it near the strong helium line (λ 4471) and the characteristic line of magnesium (λ 4481), this region being well suited for work on the Orion stars. A further reason for choosing this field of work is the fact that it has been little observed for radial velocity, and it is therefore one needing attention.

The choice of these twenty stars is from a list of something over one hundred stars of the Orion type observed by Vogel and Wilsing, exclusive of spectroscopic binaries previously known to be such. The description of the instruments used in this work is full and definite and apparently complete. Since the spectrograph has been in use a number of minor changes have been made which improve its working efficiency. For a fuller knowledge of details of instruments, methods of work, way of reduction and the combination of results, our readers are referred to the paper which is in octavo form and contains 108 pages of closely printed matter.

Near the end of the paper is an important page (106) which concerns the classification of the spectra which this study has brought out. The points made are, that the stars investigated belong to type I*b* of Vogel's classification, but, in some respects would be better represented by Miss Maury's divisions, because hers shows a very wide range of spectrum including the H and K region; that there is a disadvantage in discussing radial spectra because the plates best adapted to this kind of work are generally quite different from those most suitable for qualitative examination. In what respects the plates are different the authors do not state, unless it is by inference, in regard to density which effect faint lines; that there are advantages in higher dispersion and a consequent broadening of the lines, for these conditions enable one to judge much better of the behavior and character of individual lines than would be possible with low dispersion and a small scale; and that the stars so far observed are too few for more than a mainly empirical classification, "and any order of arrangement will represent the succession of the various spectra as regards complexity and character of the lines rather than the sequence of development of the stars themselves." This last statement is significant, and it is the language of the authors, except for the position of one word that is changed for the sake of clearness in meaning.

As already stated, the lines that have been investigated, and are to be classified on some plan, are those from the elements: hydrogen, helium, magnesium, silicon, oxygen and nitrogen. Only a few lines are yet to be identified, and the extent of the spectrum in this work was from λ 4300 to λ 4720.

From this point the authors speak of the order of the development of certain stars in this group, and the statements made are so definite that we wish our readers to have their own words. They are as follows.

"In what are probably the earliest stars of this type in order of development no lines are present with the exception of the hydrogen and stronger helium lines, and these are faint, and extremely broad and diffuse. Most of them contain the line Hγ' at λ 4542, which belongs to the series of hydrogen lines first found by Pickering in the spectrum of ζ Puppis, and some of them show the line at λ 4686, which Rydberg calls the first line of the hydrogen spectrum. Both of these lines are represented by bright bands in the spectra of stars of the Wolf-Rayet type. In the stars which appear most naturally to come next in order these lines disappear, and the hydrogen and helium lines increase in strength, at the same time becoming narrower and more sharply defined. The earliest of this

group of stars show traces of the magnesium line at λ 4481, and the silicon lines at λ 4553, λ 4568 and λ 4575. While the magnesium line, however, rapidly increases in strength, becoming in the later stars of the group one of the most prominent lines in the spectrum, the silicon lines remain comparatively unimportant. The spectra of the furthest developed stars of this sort, such as ι Herculis and β Orionis, are characterized by strong and fairly well defined lines of hydrogen and helium, a strong and narrow line at λ 4481, and traces of the silicon lines. Faint metallic lines also appear at this point, the most prominent being at λ 4550 and λ 4584, and indicate the connection of these stars with those distinguished by metallic lines. These last are represented among the stars investigated by ζ Tauri, γ Corvi, and η Leonis, and show a great decline in intensity for the helium lines accompanying the rise of the metallic lines. The magnesium line λ 4481, however, is very weak in the case of ζ Tauri, though strong in the other two stars, and this fact, together with the remarkable character of its hydrogen lines, which are of a sharpness and brilliancy not approached in any of the other stars, makes the spectrum of this star one of the most interesting that we have encountered.

"Up to this point the order of succession of the spectra seems to be fairly clear, but those containing oxygen and nitrogen lines are much harder to classify. This difficulty arises from the fact that in other respects they seem to be almost identical with those which we have just considered. There is the same rise in intensity and increase in sharpness on the part of the hydrogen and helium lines, and the magnesium line appears and develops in almost exactly the same way, reaching nearly, though never quite, the intensity which it has in such stars as β Orionis. On the other hand, we find in the earliest stars of this group the beginnings of a whole series of oxygen and nitrogen lines which develop simultaneously with the hydrogen, helium, and magnesium lines, and attain in the later stars of the group, such as β Canis Majoris and γ Pegasi, a high degree of prominence. The fact that the three silicon lines, which in the stars considered before never became at all marked features of the spectrum, now follow the behavior of the oxygen and nitrogen lines and gain in intensity with them, is of interest as showing that the stellar conditions seem to be favorable to the simultaneous development of the spectra of the three elements. An examination of these characteristics of the spectrum appears to make the relationship of this group of stars to that which we have considered before one of parallelism rather than succession. For while the order of succession of the individual stars within the two groups is so well defined as to preclude the insertion of either within the other, an attempt to make one follow or precede the other would be equally difficult, without the assumption of the absence of more connecting links than would be justified. Accordingly, it has seemed best to assume a point of division immediately after the earliest stars of the list, and to arrange the stars exhibiting no oxygen or nitrogen lines in their spectra along one branch, while the stars which are characterized by such lines proceed along the other.

"In the following table the twenty stars discussed in this paper, together with some others of this type of which we have one or more plates, are collected and arranged. Those whose spectra are very closely allied are connected with brackets, and within the brackets the individual stars are placed in the order of increasing intensities of the lines mentioned.

κ Draconis
ι Orionis
S Monocerotis
λ Orionis

Only hydrogen and stronger helium lines present with $H\gamma$ and λ 4686. All lines extremely broad and diffuse. Possibly a trace of λ 4481 in γ Orionis.

π^5 Orionis
ϵ Delphini
ϵ Cassiopeiæ
η Lyrae
ζ Draconis
τ Herculis
ι Herculis
β Orionis

All lines growing narrower and sharper, with λ4481 and helium lines stronger. Traces of silicon lines. No oxygen or nitrogen lines.

ζ Tauri
γ Corvi
η Leonis

Helium lines much weaker. Metallic lines grow stronger.

ζ Orionis
ϵ Orionis
κ Orionis

Lines stronger than above but very diffuse. Traces of λ 4481 and silicon lines. Traces of a few oxygen and nitrogen lines with strong λ 4649.

67 Ophiuchi
102 Herculis
η^4 Orionis
χ^2 Orionis
γ Orionis
ζ Persei
η Orionis
β Cephei
ζ Cassiopeiae
ϵ Canis Majoris
β Canis Majoris
δ Ceti
γ Pegasi

All lines growing narrower and sharper, with λ 4481, helium, and silicon lines stronger. Oxygen and nitrogen lines increase in number and grow sharper and stronger."

On page 105 of this volume of the Decennial Publications is found the final results of the work of Messrs. Frost and Adams, tabulated as is given below:

Mag.	Star.	R. A. h m	Decl. ° ′	Radial Velocity. km.	No. of Measures.	Epoch.	Proper Motion. R. A. s	Proper Motion. Decl. ″	Proper Motion. Great Circle. ″
3.0	γ Pegasi	0 08	+ 14 38	+ 5.4	12	1902.06	0.0000	− 0.013	0.013
3.7	ζ Cassiop.	0 31	53 21	+ 2.9	6	1902.10	+ 0.0024	0.007	0.023
3.6	ϵ Cassiop.	1 47	63 11	− 5.9	8	1902.08	0.0058	0.017	0.043
3.1	ζ Persei	3 48	+ 31 35	+ 22.1	7	1901.95	0.0009	0.017	0.020
0.3	β Orionis	5 10	− 8 19	20.7	24	1901.95	+ 0.0001	0.001	0.002
1.9	γ Orionis	5 20	+ 6 15	18.0	10	1901.98	− 0.0004	0.019	0.020
1.8	ϵ Orionis	5 31	− 1 16	26.7	7	1902.05	0.0000	0.002	0.002
1.9	ζ Orionis	5 36	2 00	18.3	7	1902.52	+ 0.0005	0.007	0.010
2.2	κ Orionis	5 43	9 42	17.1	10	1901.88	+ 0.0001	− 0.005	0.005
2.0	β C. Maj.	6 18	17 54	32.6	5	1901.84	− 0.0004	0.000	0.006
1.5	ϵ C. Maj.	6 55	− 28 50	27.2	4	1902.61	+ 0.0004	− 0.001	0.005
3.6	η Leonis	10 02	+ 17 15	+ 3.5	5	1902.31	− 0.0001	− 0.012	0.012
2.8	γ Corvi	12 11	− 16 59	− 7.0	6	1902.27	0.0113	+ 0.011	0.162
3.9	τ Herculis	16 17	+ 46 33	12.7	6	1902.21	0.0012	0.031	0.033
3.3	ζ Dracon.	17 08	65 50	14.4	8	1902.19	0.0021	+ 0.020	0.024
3.9	ι Herculis	17 37	46 04	16.4	6	1901.92	− 0.0010	− 0.006	0.012
4.0	67 Ophiu.	17 56	2 56	3.1	4	1902.47	+ 0.0003	0.016	0.017
4.5	102 Herc.	18 04	20 48	10.8	5	1902.62	+ 0.0003	0.011	0.012
4.5	η Lyrae	19 10	38 58	9.1	6	1902.74	− 0.0002	0.004	0.005
4.1	ϵ Delphini	20 28	+ 10 58	− 26.2	4	1902.55	+ 0.0006	− 0.026	0.027

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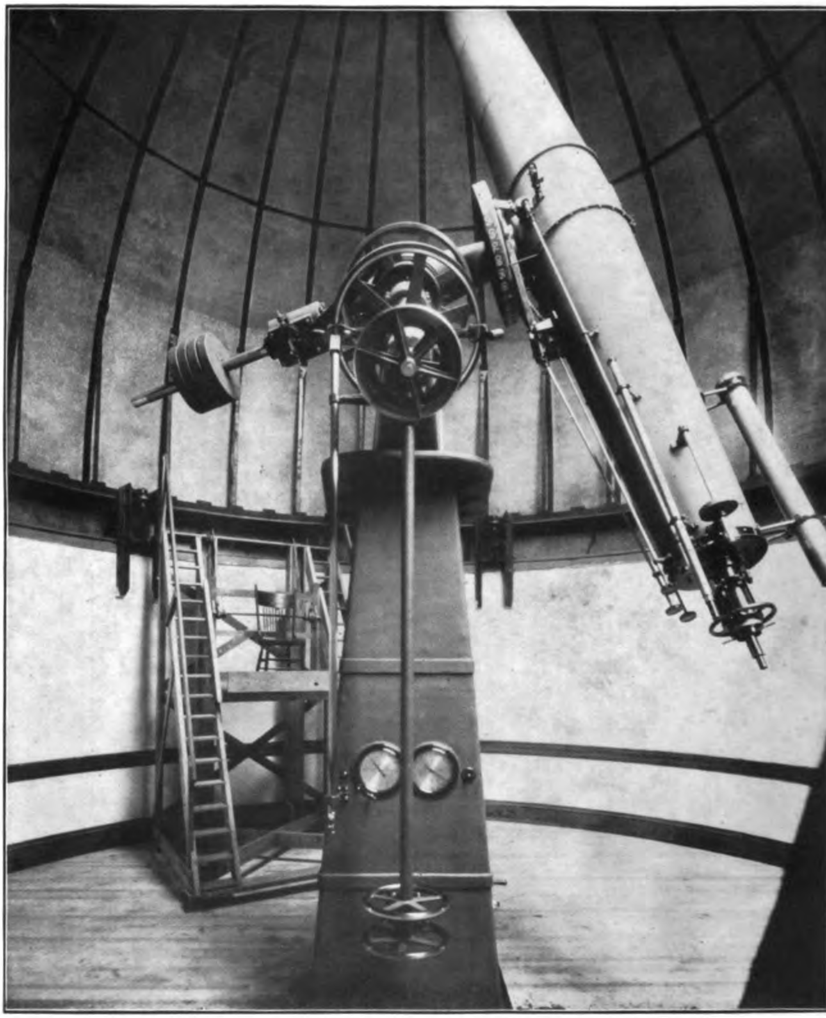


THE NEW SIXTEEN INCH TELESCOPE AT
CINCINNATI OBSERVATORY.

Popular Astronomy.

Vol. XII No. 7. AUGUST AND SEPTEMBER, 1904. Whole No. 117.

THE NEW SIXTEEN-INCH TELESCOPE OF THE CINCINNATI OBSERVATORY.

J. G. PORTER.

Through the indefatigable efforts of Ormsby McKnight Mitchel there was erected at Cincinnati in 1845 one of the largest refractors at that time in existence. In 1873 the observatory was removed from the original sight on Mt. Adams contiguous to and overlooking the business part of the city, to Mt. Lookout about five miles distant. The new building was provided with a thirty foot dome,in anticipation of the time when it might be possible to procure a larger instrument. That time has now come, and two years ago the contract was given to the Alvan Clark and Sons' Corporation for a sixteen inch equatorial to be constructed on modern lines. This was installed in March of the present year. The old Mitchel telescope is to be placed in a smaller observatory which will be known as the O. M. Mitchel Building.

The disks for the sixteen inch objective were obtained from the celebrated optical works of Feil, and were figured by Mr. C. A. R. Lundin, optical expert of the Alvan Clark Company. They are practically free from imperfections; the color correction is as perfect as can be obtained with a glass of this size, and the defining power is exquisite. Doubles as close as 0″.4 have been readily separated and prob ably under exceptionally favorable circumstances still narrower pairs could be divided, since the theoretical distance for a glass of this size is 0″.3. The two lenses of the objective are separated by about three inches. The space between them can be ventilated by opening a sliding shutter. There is also a trap door just behind the objective for ventilating the tube itself. From this construction there results the rather peculiar circumstance that the focal length of the telescope is longer than the instrument itself. Thus the focal length determined by the value of the micrometer screw in connection with

the linear distance of the threads is 246 inches, while the length of the tube from the outside of the object glass to the focal plane is only 242 inches.

The masonry column which supports the telescope is about 25 feet in height above the floor of the basement, and 10 feet in diameter at the base, tapering to 8 feet at the top. Upon this is securely bolted a cast iron shoe furnished with three bearing surfaces. Midway between the two bearings on the north end a one and one-fourth inch steel pin projects upward through a corresponding hole in the lower end of the pier. Around this pin the whole pier may be turned in azimuth. The bearing at the south end consists of a rectangular block upon the upper surface of which rests the screw for level adjustment, and working against the sides are the two opposing screws for adjustment in azimuth. When the adjustment is completed the pier is tightly clamped to the shoe.

The pier itself is rectangular, 4 feet 9 inches by 3 feet 11 inches at the bottom, and narrowing to 3 feet by 1 foot 8 inches at the top. It is made in three sections and firmly bolted together. The height to the foot-board is 10 feet 3 inches. Doors on each side of the lower section give entrance to the interior of the pier, while glass doors on each side of the upper section give access to the driving clock.

The headstock is so shaped that the upper bearing of the polar axis is over the center of the pier, and the center of gravity of the tube and counterpois weights falls about 15 inches from the north side of the pier. Above the bearing is placed a large, broad-rimmed friction wheel which is forced against the lower side of the axis by means of a lever with sufficient pressure to carry the moving parts of the telescope. The slight downward thrust of the polar axis is taken by an adjustable ball bearing at the lower end.

The worm wheel, 32 inches in diameter, is cut with such accuracy that no irregularities whatever have yet been detected in the motion of the telescope. The driving clock is run by a four hundred pound weight inside the pier. It has a fan governor, and the fans are held from flying outward by a spring on the shaft, by tightening or loosening which the speed may be altered. The electrical control is effected in the following manner: Fitted loosely on an axle of the wheel-work that revolves once a second is an arm, one end of which is connected with the axle by a spiral spring, the other end being a pallet. Engaging this pallet is a detent worked by an armature connected with the control clock. Once each second the arm is released and flies around to be caught again by the detent, the wheel-work in the meantime running on and coiling the spiral spring. The motion obtained in this way

is very equable. In fact, the image of a star even with the highest powers appears absolutely stationary in the field, and the whole instrument is so rigid that there is not the least vibration or tremor.

The hour circle is read from the floor by a reading telescope on the south side of the pier. It is graduated to minutes of time, and divided by the vernier to five seconds. The declination circle, similarly, is read from the eye end. The smallest reading is thirty seconds of arc. On the rims of both circles are coarse graduations which may be read from the floor or observing chair. In order to set the telescope conveniently two hand wheels are placed on the south side of the pier. The dials above them show the position of the instrument. The declination dial is divided to single degrees, and the right ascension dial to five minutes of time. The latter is driven by clock-work, so that no computation of hour angle is necessary. In this way the instrument may be easily and quickly pointed upon any object, the dome turned and the observing chair adjusted before leaving the floor.

The instrument is illuminated by small electric lamps. Those for reading the hour circle are switched on from the floor, the others from the eye end. At present these lamps are run by a storage battery of five cells, but eventually it is hoped to obtain the city current.

Clamps and slow motions in both right ascension and declination are operated from the eye end. In order to facilitate the exchange of eye-pieces and micrometer a modified bayonet joint is used, the clamping being done by a circular collar. Another advantage of this arrangement is that the micrometer may be removed and put back without altering the adjustment of parallel. The micrometer now in use is one made for the eleven inch by Mr. Saegmuller. It is very convenient in arrangement. The value of one turn of the screw is a little less than 17″. The new telescope is fitted up solely for visual work, and it is expected for the present to devote considerable time to the observation of comets, minor planets and double stars. Possibly other lines of work will be decided upon later.

AN EXPLANATION OF THE MARTIAN AND LUNAR CANALS.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

When the suggestion of vegetation was first offered to explain the so-called seas and canals of Mars,* the difficulty was strongly felt that while it readily explained their changes of area, shape,

* Science 1888, XII, 82. Astron. and Astro-Physics 1892, XI, 670.

and color, it did not satisfactorily explain the long slender forms of the canals. That these might be due to narrow and therefore invisible water courses was an obvious idea. Professor Lowell in adopting these views added to them the hypothesis of an artificial formation. If the canals were really as straight and uniform as they are generally drawn, it was certainly hard to see how they could owe their origin entirely to natural causes. But now that some of the English experimenters, Messrs. Lane, Maunder, and Evans have cast doubt on the existence of many of the straight canals, the hypothesis of an artificial origin is materially weakened.

Another difficulty which early presented itself was to explain what caused the water to flow through the narrow channels, unless we supposed it was artificially pumped through them. This has always seemed to the writer to be the chief difficulty with the whole explanation, but Professor Lowell has now courageously taken the bull by the horns, and adopted the pumping hypothesis.* If the surface is level, gravity would not come into the question, but we may well ponder upon the amount of energy transformed into work which could furnish enough water to irrigate anywhere from a hundred thousand to a few million square miles of surface.

When the canals on the Moon were discovered, it was thought that they might throw some light upon this puzzling question. It must be remembered that the Moon is about 200 times nearer than Mars at an average opposition, and we can readily imagine that if we could increase the power of our telescopes 200 times, we might make quite a number of interesting discoveries upon Mars.

Upon the Moon as upon that planet, several canals frequently radiate from a single lake, but what was most unexpected, the lakes are sometimes found in the bottom of a lunar valley, and sometimes upon the crest of a crater wall. As is the case with Mars also, when the Sun rises upon them, and the snow melts, the lakes and canals develop and become conspicuous, subsequently fading out at sunset, which corresponds to the Martian winter.

It has been shown† that in the lunar crater Alphonsus there are eight variable spots, or lakes as we should now call them. In the exact center of each, excepting the largest one, is found a minute craterlet. In the largest lake there are two large crater-

* Proceedings Amer. Philosophical Society 1903, XLII, 364.

† Harvard Annals XXXII, 92.

lets and five small ones. The canals radiate from the lakes and therefore from these craterlets. The symmetrical arrangement of the lakes about the craterlets in so many instances indicates a causal relation between them, and that the vegetation of the lake, if such it be, owes its origin to some volcanic action.

In the case of several of the larger craters, notably Tycho, we find a similar radiating structure, and in the case of Tycho even a dark spot or halo at the center. In this case the whole formation is upon so large a scale that its elementary structure can be clearly distinguished. The white radiating lines or bands are seen to be due to numerous minute craterlets, each giving out a triangular white streamer, the allignment of these streamers producing the general effect of a white band. It is probable that this observed regular distribution of the craterlets is due to their lying along invisible cracks radiating from the main crater. It is much the same as the great volcanoes of the Andes, which stretch in a straight line for over 2000 miles between Peru and the Straits of Magellan. The Alaskan volcanoes lie upon a uniformly curved line of nearly equal length. Most of the terrestrial volcanoes are distributed along similar lines. This line formation is generally considered by geologists to be due to subterranean lines of weakness or cracks in the Earth's crust. Such being the case, it seems probable that the canals on the Moon lie along similar invisible cracks radiating from the small craterlet at the center of each lake. These cracks are not always straight but such is their general tendency. Under favorable illumination small cracks are found to be very common upon the surface of the Moon, and in the cases of Petavious, Alphonsus, and Atlas that class of cracks that we have designated from their shape as river-beds are seen to be intimately associated with the lakes and canals.* It is believed that enough water vapor and carbonic acid escape from the central craterlet and flow down its sides to develop the vegetation upon its slopes, and that the smaller quantities escaping from various points along the radiating cracks similarly develop the vegetation which shows along their sides. In addition to the escaping vapor, water itself might issue from the subterranean crack and percolating through the soil be evaporated from its surface.

It is not thought that there is any transfer of vapor lengthwise of the crack, but that on account of the lack of external atmospheric pressure the vapor rises quietly directly from the lower

* Harvard Annals XXXII 98 and 112, see also Plate VII.

regions, owing to the internal heat of the Moon. As soon as the exterior is sufficiently warmed by the Sun, the vapor and gas would begin to appear. On account of the rarity of the atmosphere, instead of rising they would immediately spread themselves along the surface of the ground. Even in desert regions upon the Earth we should therefore scarcely expect to find similar formations, unless actually irrigated by water, instead of water vapor. In its physical condition Mars seems to occupy an intermediate position between the Earth and Moon.

It seems to the writer that the merit of this explanation lies not so much in its novelty, but rather because it is founded so largely upon observed facts.

HARVARD COLLEGE OBSERVATORY,
June 1, 1904.

PTOLEMAIC AND COPERNICAN SYSTEMS OF GALILEO.

C. C. HUTCHINS.

On a high hill overlooking the City of Florence stands an old villa flanked by a square tower, upon whose summit still creaks a rusty weather-cock in the form of a rooster, the arms of an ancient family that once reigned here, and from which the place is still called Torre del Gallo,—the Tower of the Rooster. The tower overlooks one of the fairest scenes on earth and is forever consecrated for men of science; for here once lived Galileo, and from the tower's summit made some of those observations that mark the beginnings of physical astronomy. The lower rooms contain many relics of their former master. Here are telescopes, large and small, made by Galileo's own hand, other philosophical apparatus, portraits and correspondence.

The inspiration that comes from seeing and handling the tools of a great master of the art that we, however humbly, practice, imparts a stimulus to learn something of the workings of his mind and of his manner of expression. Morever the primary sources of our information must always remain the most valuable. I have therefore thought it might be of interest to present some passages from the writings of Galileo, translated as literally as possible from the Italian of 300 years ago, with such little comment as will serve to make them somewhat more connected and intelligible.

I Dialoghi sui Massimi Sistemi Tolemaico e Copernicano was finished in 1630 and published with the universal applause of all scientific men, two years later. Galileo was therefore 68 years old at the time of the appearance of the book that presents his ripest thought and was

his last important work. It was the fate of genius that instead of crowning his fame it brought the indictment of the Inquisition that weighted his last years with grief and disgrace.

The edition here used, (which may be had for the modest sum of 17 cents), was printed in Milan in 1883. It is a book of 408 closely printed pages. The work is in the form of a dialogue between three friends; which form, says Galileo, "not being constrained to the rigorous observance of mathematical laws, gives room for digressions not less interesting than the main subject."

As a writer Galileo was extremely prolix, a fault made easier in this case by the dialogue form; and then the reader will often feel doubt if all those numerous digressions are actually as interesting as the main subject. Again, the world was still much given to the scholastic method, whose object was not so much to settle the question by any method whatever, as to sharpen the wits with endless argumentation; and finally, men's minds were so bound by Aristotle, and their methods of thinking so determined by his philosophy, that nothing but an overwhelming array of arguments presented with the most hair-spun logic could get a hearing. It was Aristotle and the Peripatetics, who, though preserving for many years the only existing science, yet now stood like an iron wall in the path of its progress.

We all know the story of old Scheiner who dismissed his pupil for declaring that he had seen spots on the sun, whereas, to Scheiner's certain knowledge, Aristotle said nothing about them. Here is one from the book before us told by Galileo to show the sort of opposition that he had to contend against.

"I found myself one day in the house of a much esteemed Venetian physician, where some for study and others out of curiosity occasionally assembled to see certain anatomical dissections made by the hand of one truly gifted and expert in that art. And it came to pass on this day that the object of research was the origin and starting point of the nerves, concerning which there is a famous controversy between the followers of Galen and the Peripatetics. The anatomist showed how, starting from the brain and passing through the neck, the greatest nerve-slock extended along the spine and branched through the whole body, but that a single filament, thin as a thread, reached the heart. Turning to a gentleman whom he knew for a peripatetic philosopher, and because of whose presence he had with extraordinary diligence discovered and shown all, he asked him if he now felt sure and satisfied that the origin of the nerves was in the brain and not in the heart; upon which the philosopher after some consideration replied: 'You have made me see this thing so openly and manifestly,

that were not the text of Aristotle to the contrary, which plainly declares that the nerves originate in the heart, I should be forced to confess it for true.' "

There are three speakers in the dialogue, Salviati, through whom Galileo speaks; Sagredo, an open-minded and intelligent gentleman who often adds valuable material to the discussion and Simplicio, the bigoted peripatetic whose name is suggestive and who can never be brought to see anything or to admit anything except that Aristotle can by no possibility be wrong. In his foreword to the reader Galileo says: "The work is divided into three parts. First, I shall try to show that all experiments made upon the earth are insufficient means for concluding its motion; but are equally well adapted either to an earth in motion or at rest; and I hope under this head to bring out many observations unknown to the ancients. Secondly, the celestial phenomena will be examined and the Copernican hypothesis so reinforced that it should remain victorious. In the third place I shall put forth an ingenius theory. Many years ago I said that the unsolved problem of the flux of the sea should receive some light, admitting the motion of the earth. This saying of mine, flying from mouth to mouth, has found charitable fathers who have adopted it for saying of their own. Now that there may never come some stranger, who fortifying himself with our arms, shall blame us for too little publicity in an affair so important, I have determined to so develop the probability of this theory as to make it persuasible, given that the earth moves."

He begins the book with some very elementary geometrical problems and goes on to treat of many cases of motion. It is not intended here to give a synopsis of the book, but to select a few passages which for one reason or another are of more striking historic or intrinsic interest.

In discussing the case of two motions imparted to an object at the same time, Sagredo uses as illustration a stone let fall from the masthead of a ship and says: "If it be true that the impetus with which the ship is moving remains indelibly impressed upon the stone after it separates from the mast, and that this motion brings no impediment or retardation to the motion in a right line downwards natural to the stone, there must follow an effect of a marvelous nature. Let the ship be at rest and the time of fall of the stone from the top of the mast be two beats of the pulse; now let the ship move from the same place. The stone will fall in the same two pulse beats, in which time the ship will have moved, for example 20 braccia,* so that the true motion of the stone will have been a transverse line much longer than the first right

*The braccio, plural braccia, was about 17 feet.

line which is simply the length of the mast. This increased distance the stone passes over in the same time. Let us suppose again the motion of the ship to be more rapid, so that the stone in falling must pass over a transversal longer than the first; and finally, the velocity of the ship increasing as much as you will, the stone in falling describes ever longer and longer transversals and passes them all in the same two pulse beats.

"Or if from the top of a tower we level a colubrina" (small cannon) and with this shoot parallel to the horizon, however little or much load be put in the piece, so that the fall 1, 4, 6 or 10 thousand braccia away, all these shots will move equal times, and each equal to the time the ball would consume in moving from the mouth of the piece to the ground, if let fall without impulse simply down the perpendicular."

The following two passages show the sharpness of Galileo's observation in common things, from which things he draws endless fund of illustration. "Concerning this matter of projectiles there came to my mind some very curious problems, the first of which is this: I have often observed with wonder while watching the players at top-shooting, that their tops departing from the hand go through the air at a certain velocity, which is much increased when the top reaches the ground and if spinning about they strike some obstacle that causes them to bound aloft, they go through the air slowly enough, but refalling to earth, they return to their former high velocity. But what is still more wonderful, I have also observed that not only do they move more rapidly upon the earth than in the air, but of two passages made, both upon the earth, sometimes the motion in the second passage is more rapid than is the first. Now what do you say to that Signor Simplicio?" Signor Simplicio says first, that he has never seen it himself; secondly, that he does not believe it, and finally if it were shown to him he should attribute it to magic. The discussion then goes on to show that if the motion of rotation of the top were the other way with reference to the direction of its projection the top would be retarded when on the ground, or might possibly fall dead; whereupon Sagredo makes the following noteworthy contribution:

"And in this lies the solution of that effect which expert players of tennis make use of to their advantage; for they deceive their adversary by cutting, (for such their term is) the ball that is, they serve the ball with the racket held obliquely so that the ball acquires a motion of rotation upon itself contrary to its motion of projection. From this it follows that upon touching the ground, the rebound, which if the ball did not turn would carry it towards the adversary giving him the

accustomed opportunity to return it, remains as dead, and the ball bores into the earth or rebounds much less than usual, and the chance of returning it is lost. We also see those, who, playing with a ball of wood to see who shall come nearest to a given mark, when they play in a stony street and full of obstructions, make the ball deviate in a hundred different ways, nor go directly towards the mark, to escape them all. They throw the ball, not spinning along the street, but through the air as though it were a flat disc. But because in throwing the ball it leaves the hand with a motion of rotation imparted by the fingers, whenever the hand is held under the ball, as it commonly is, the ball striking the ground near the mark, between its motions of projection and rotation, shoots away. Therefore to make it stop it is grasped with the hand above and the ball beneath, by which the contrary rotation is imparted, and striking, there it stops or advances but little." Behold how old many of our newest inventions! The reader will observe that we here have described exactly the method of holding and throwing the ball as practiced by our ball pitchers; with the same result, namely, to make the ball "deviate in a hundred different ways nor go directly towards the mark."

It will be remembered how Galileo at the leaning tower of Pisa demonstrated the falsity of the Aristotelian doctrine that heavy bodies fall more rapidly than light ones in proportion to their weight. Here is Galileo's statement of the law of accelerated motion.

"Before all we must consider how the movement of heavy descending bodies is not uniform, but, starting from a state of rest is continually accelerated—a fact known to all. But this general cognition is of no value if we know not according to what proportion this increase is accomplished; a conclusion that has remained unknown to all philosophers until our own time and first made known and discovered by our academician and common friend, who, in some writings of his not yet published, but shown to me and certain other friends in confidence, demonstrates that the acceleration of a heavy body in a right line is accomplished according to the uneven numbers taken *ab unitate;* that is, taking whatever equal intervals of time you will, if in the first interval starting from rest the body passes over one space, for instance a rod, in the second interval it will pass over three rods, in the third five, in the fourth seven, and so successively according to the odd numbers; which in sum, is the same as saying that the spaces passed over by the moving body have among them the double proportion that have the times in which the spaces are measured; or we may say, the spaces passed over are to each other as the times squared."

Galileo died the year of Newton's birth, 1642; it was consequently

many years before much was known of gravity between distant masses; consequently when Galileo applied his rule to finding the time of fall of an object from the sphere of the moon to the earth, he gets but 3 hours 22 minutes and 4 seconds on the assumption that the moon is 196,000 miles distant.

Notwithstanding want of the definite knowledge that Newton later supplied Galileo had a conviction that whatever caused one celestial body to move caused motion in all. "I am asked," he says, "what are the principles by which the terrestrial globe is moved in its annual course through the zodiac and in its daily motion in the equator. I say they are similar to those by which Saturn is moved in the zodiac in 30 years, and in a time much more brief about itself in the equinoctial, as the appearance and disappearance of its collateral globes shows.

It is something similar to that by which it is conceded without denial that the sun courses the ecliptic in a year and revolves about itself parallel to the equinoctial in less than a month, as is shown by his spots. It is something similar to that by which the Medicean stars course the zodiac in twelve years and likewise revolve about Jupiter in minute circles and in very brief times."

Notice in the above passage the reference to Saturn's collateral globes, for as such seemed the ring in Galileo's feeble telescope.

Galileo did not himself seem to attach much weight to his explanation of the tides, viewing it rather as a plausible theory than a demonstrated fact. It had already been suggested by more than one, Kepler among others, that lunar influence was influential in causing the periodic flux and reflux of the sea. This notion Galileo rejected, and did so justly, because his mind could not accept a mere *influence,* invented for the occasion, and the idea that the lunar rays expanded the water under them he showed to be foolishness. Therefore he sets down those believers in lunar influence as being among the number apt to to invent and believe fables.

Galileo attributed the tides to irregularity of motion of the earth on its axis, caused by combination of its daily and annual motions. When the axial motion was retarded, the water would flow forward, and when accelerated, back again.

Although Galileo's demonstration of the earth's periodic retardation and acceleration was unsound, his argument for the earth's rotation derived from motions of the solar spots was perfectly sound and convincing. His only assumption was that the sun revolves with its axis parallel to itself. To have invented and constructed the telescope, therewith discovered the sun's spots and their peculiar motions, thence correctly to have inferred the earth's motion would have brought fame

enough for one man, had he done nothing else. As Galileo in another place says: "To apply one's self to great inventions starting from very small beginnings, to infer under first and feeble impressions content of a marvelous kind is not for common minds, but these are the thoughts and concepts of master spirits."

In the following passage, treating of the sun's spots and which I have given somewhat more fully, Galileo is of course speaking of himself in the third person.

"He was the first discoverer and observer of the solar spots, as of many news things celestial, and these he discovered in the year 1610, being then lecturer in mathematics in the University of Padua; and both there and at Venice he told of them to divers. A year later he showed them at Rome to many gentlemen. He was the first that, contrary to the opinion of the too timid and too gelous of the inalterability of the heavens, affirmed those spots to be material, quickly formed and quickly dissolved; that as to situation, they were contiguous to the body of the sun, about which they revolved, or rather were borne by this same solar globe, finishing their rotation in about a month, the time in which the sun itself turns upon its own centre.

This motion was not at first judged the sun performed upon an axis perpendicular to the plane of the ecliptic, the arcs described by the spots upon the disc of the sun appearing to the eye straight lines parallel to the plane of the ecliptic. These lines were in part changed by sundry accidental movements wandering and irregular, through which the spots changed their location among themselves fortuitously, now crowding together, now separating, and some moreover dividing and changing figure in the most extravagant manner.

Although such inconstant mutation might alter in part the first period run by these spots, this did not change the opinion of our friend to thinking that such changes were for any fixed and essential reason, but he continued to believe that all apparent changes were derived from those accidental ones, just as it would seem to one who from some far region should observe the motion of our clouds. These he would discover to be moving with great and constant velocity, borne about by the daily motion of the earth, (if such were), in 24 hours in circles parallel to the equator, but altered in part by accidental movements caused by the winds casually driving them towards different parts of the world. * * * It came to pass that our friend, (occupied by other studies), omitted continuous observations for some time, and only occasionally making a few desultory ones for the pleasure of some friend, until, after some years encountering with me at my villa one of those single large and dense spots, invited also by a most transparent and

continuous serenity of the heavens, he made at my request observations of its whole transit, putting down upon paper most faithfully from day to day the position of the spot at the hour when the sun came to the meridian. He perceived that the path of the spot was not at all a straight line, but somewhat curved, whence he determined to make other observations from time to time, to which undertaking he was greatly stimulated by an idea that suddenly came to his mind, and which he expressed to me as follows: Filippo, it seems to me that here the way opens to great things, for, if the axis about which the sun revolves is not perpendicular to the plane of the ecliptic, but inclined to it, as this curved transit just now observed, indicates, such conjecture have we of the state of the sun and of the earth that none so firm or so conclusive has yet been presented from any other circumstance. I excited by such great promise, urged him to explain to me his idea. And he: If the annual motion of the earth be in the ecliptic about the sun, and if the sun be located in the centre of the ecliptic, and in this revolves about itself, not about the axis of the ecliptic, (which would be the axis of the annual motion of the earth) but about one inclined, it must be that strange changes would appear to us in the apparent motions of the solar spots, provided that the solar axis persists perpetually and unchangeably at the same inclination and in the same direction, toward the same point of the universe. Therefore to us, borne by the terrestrial globe in its annual motion, first it must happen that the transits of the spots, should sometimes appear as straight lines; but this twice in the year only, but at all other times they would show as arcs sensibly curved. Secondly, the curvature of these arcs for one-half of the year would appear in the contrary direction from that shown in the other half; that is, for six months the convexity of the arcs would be towards the upper part of the solar disc, and for the other six towards the lower. Thirdly, the spots, beginning to appear, and, so to say to rise to the eye upon the left side of the disc, and going on to disappear and set upon the right, the eastern bounds, that is, those of first appearance, for six months will be lower than the bounds of disappearance opposite, and for the other six months, the reverse will be true, that is, the spots rising at more elevated points, and from thence descending in their course will set at lower points. For two days only will the points of rising and setting be equilibrated after which the inclination of the course of the spots commencing very slowly and increasing from day to day in three months will attain the greatest obliquity, and from thence commencing to diminish, in three months will be reduced to equilibrum again.

The fourth marvel is that the day of greatest obliquity will be the

same as that of passage in a right line; and on the day of no obliquity the arc of passage will be most curved. At other times when the inclination is diminshing and moving towards equilbrium, the curvature of the arcs of transit will be increasing.

Alas for Galileo! For such lofty flights of geuius the church had neither understanding nor appreciation. How different had it been with science if the inquisiton had had even the grace of poor Simplicio to say: "I know myself incapable of deciding in matters so weighty, and therefore I will remain neutral, with the hope that there may come a time, when, illuminated by more lofty contemplations than on these our human discourses my mind may be unveiled and the darkness that clouds it, dispelled."

THE SWASEY RANGE FINDER.

W. W. PAYNE.

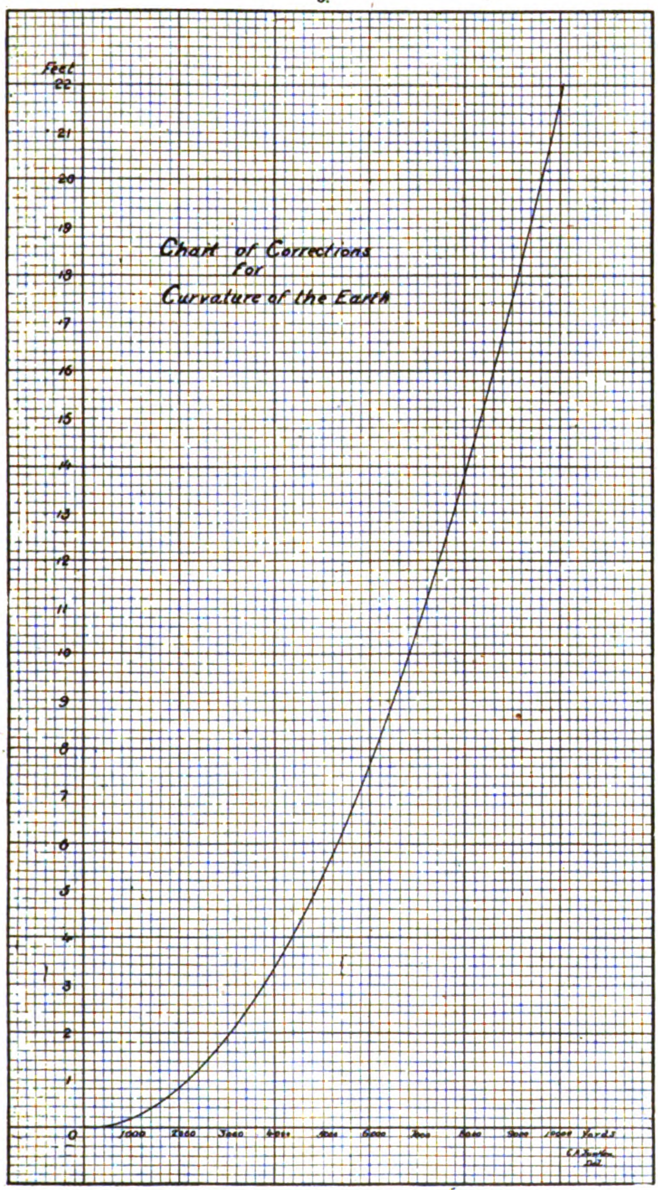
We have been much interested in the description of a new instrument under the name of The Swasey Depression Position Finder, constructed by the Warner and Swasey Company, Cleveland, Ohio.

The new instrument has been adopted in the War Department of the United States, and the Chief of Ordnance has published a detailed description of it for use in the Government Service. The description specifies plainly and fully how to assemble the parts of the instrument and to adjust it for the work it is intended to do. It is chiefly used at and for the sea coast and harbor fortifications; for by it, the distance and position of any ship, up to 12,000 yards, can be determined within a limit of error of about half of one per cent. The relation of the position of the Range Finder to each gun in any particular fortification is plotted accurately, so that the range and azimuth position of a distant ship can be relocated for each gun instantaneously when so desired. Every fortification is supposed to have at least one of these range or position finders.

All successful range finders work on the common principle of solving the right angle triangle, the base and the right angle being constant; the accurate measurement of the angle at the other end of the base gives all the needed data for determining the distance of the ship which is at the intersection of the two longer sides of the triangle, and to which the telescope of the Range Finder is pointed.

The United States War Department uses two types of the Swasey Range Finder. One, known as the "Horizontal Base", Range Finder, and the other as the "Vertical Base" or Depression Range Finder.

The Horizontal Base instrument requires two telescopes, or their



equivalent, one at the end of the base, fixed at 90 degrees, and the second at the other end of the base, and adjustable so as to measure closely the angle desired.

The Vertical Base, or Depression Range Finder must be placed at an elevation over-looking the harbor, the altitude of its location above

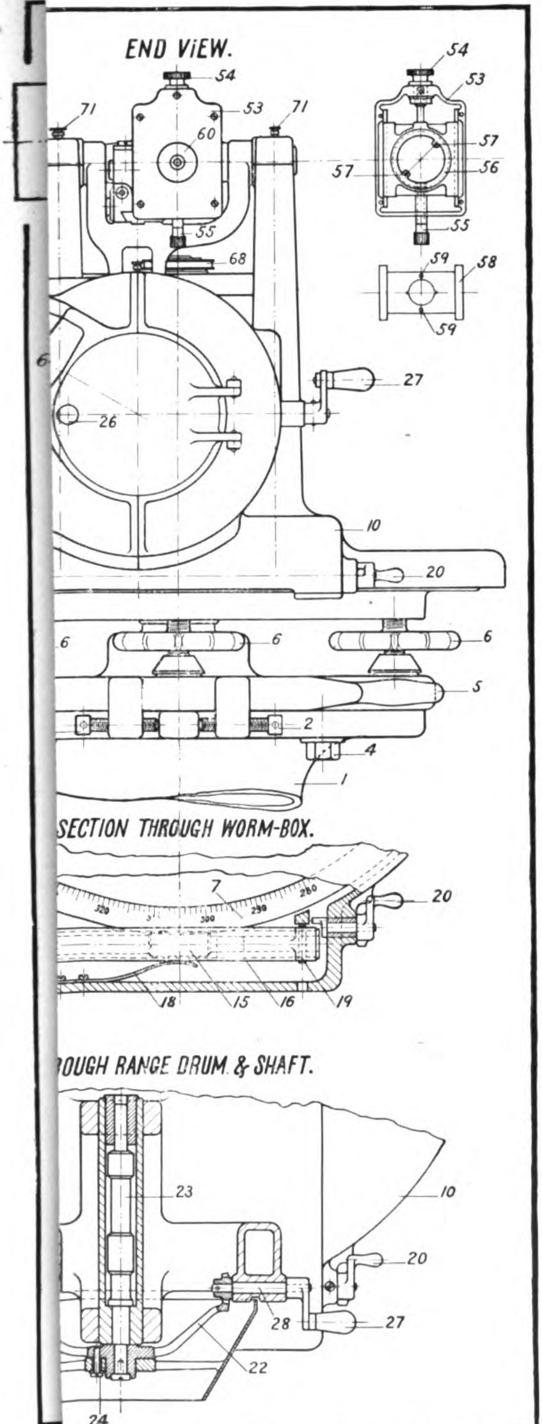
mean low tide serving as the base line of the triangle, at the acute angle of which is the ship whose distance is to be determined. It will be evident that to make these observations, the telescope must be pointed to the water line of the ship, and then the angle of depression can at once be read which completes the chief data needed for finding the distance desired. In the use of this important type of the Range Finder corrections must be applied for the curvature of the Earth, height of the tide, and, also, for refraction. Provision for these corrections has been made in the construction of the instrument. The pamphlet referred to above, and the cuts herewith presented particularly describe this type of Range Finder. Our readers will have some idea of the usefulness of these important instruments if we say that the Warner and Swasey Company have already made 100 of these Range Finders for the War Department of the Government, and that there is now an order for even a larger number of them in hand and in process of construction.

When one looks at these fine cuts, and notices how promptly and accurately the instrument they represent does its work, and sees how quickly the practiced observer will get his data, make delicate corrections and get his reliable and very useful results in times of peace or war, he can never cease to wonder at the triumphs of modern skill and ingenuity so closely shown in work like this. The accompanying cut (one-fourth size of that found in the description previously referred to) gives a clear idea how the correction for curvature of the Earth is found. It may be enough interesting to some of our readers for them to test the accuracy of the curve, by reference to the mathematical formula commonly used for computing this correction.

The following table will aid the interested reader in getting a fuller and better understanding of the Depression Position Finder, when a close study of the cuts is desired.

NOMENCLATURE.

1. Base
2. Azimuth zero set screws.
3. Azimuth plate.
4. Azimuth plate bolts.
5. Azimuth plate handles.
6. Leveling screws.
7. Azimuth circle and worm gear.
8. Azimuth pointer.
9. Vertical spindle.
10. Cradle.
11. Cradle spindle bearing.
12. Adjusting levels.
13. Azimuth drum.
14. Azimuth drum handle.
15. Worm screw.
16. Worm box.
17. Worm box pivot.
18. Worm box spring.
19. Worm box adjusting screw.
20. Worm box crank.
21. Range drum.
22. Range drum gear.
23. Range drum shaft.
24. Range drum screws.
25. Range drum cover.
26. Range drum door.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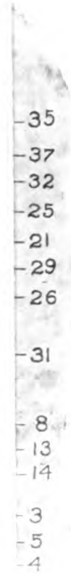
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PLATE XIV.

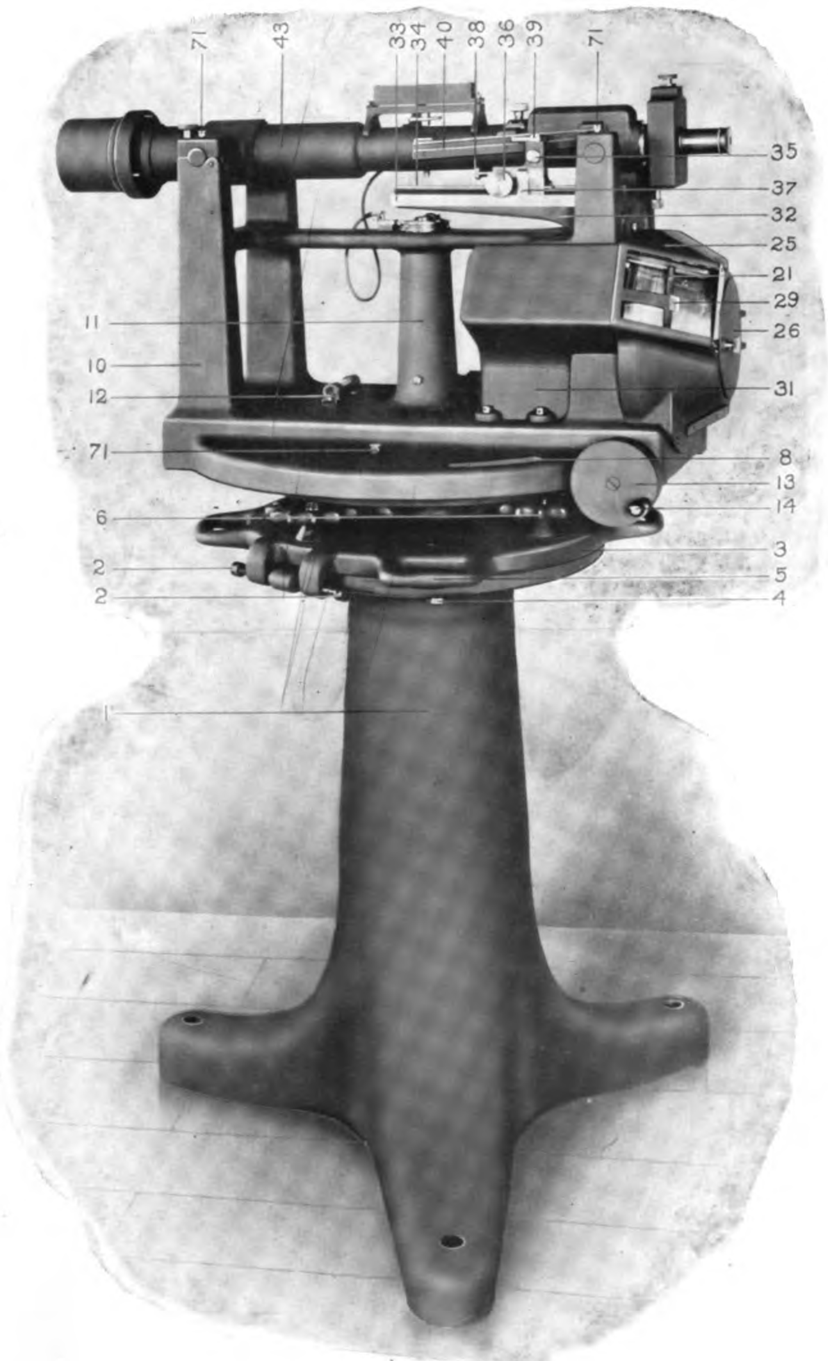
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PLATE XV.

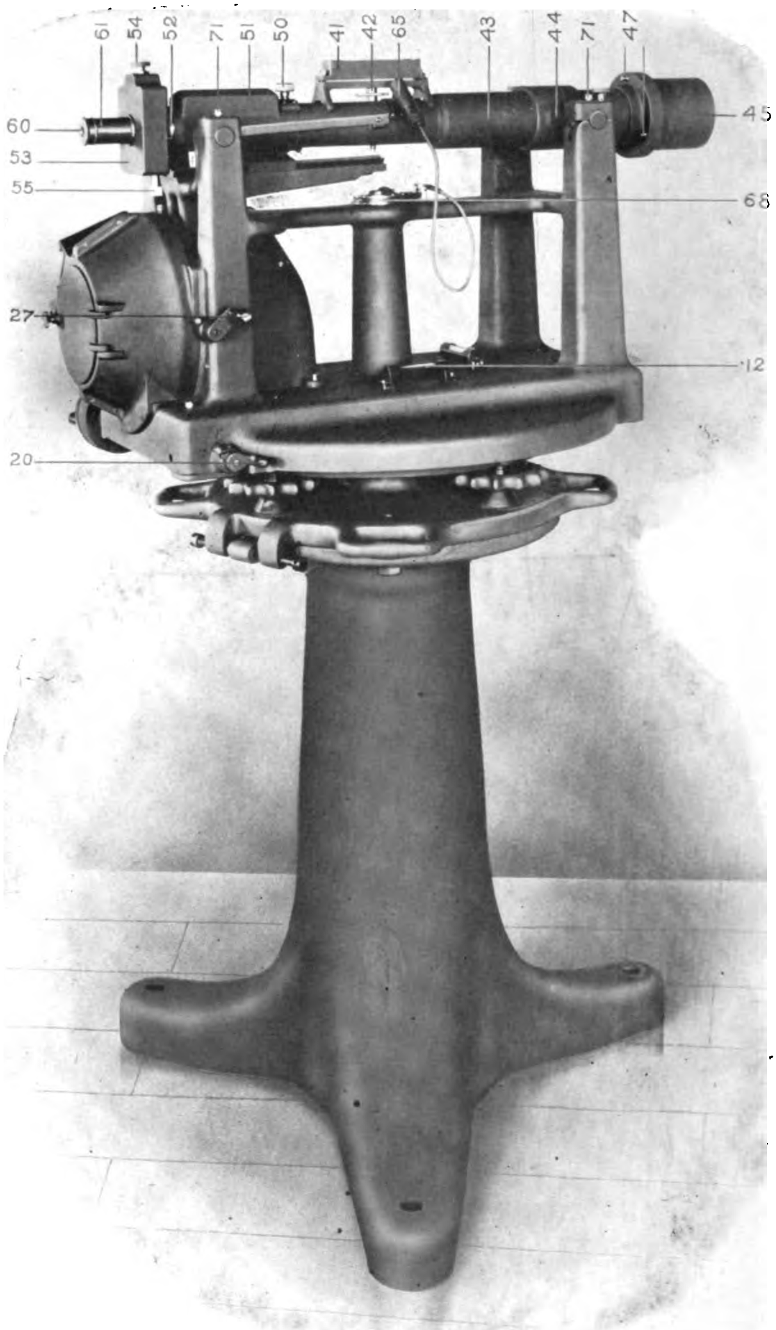
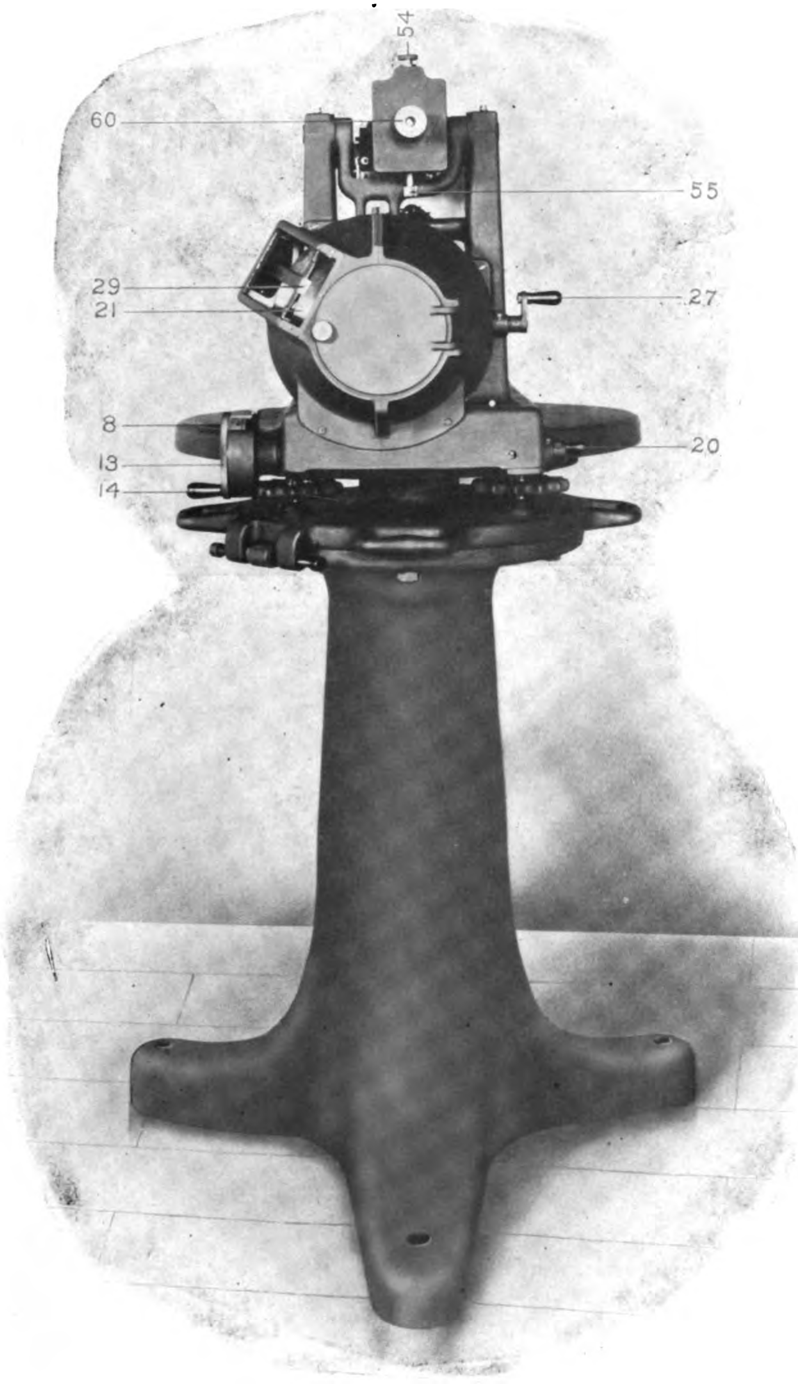


PLATE XVI.



27. Range crank.
28. Range crank shaft and pinion.
29. Range pointer.
30. Range pointer arm.
31. Range pointer cover.
32. Bell crank lever.
33. Height scale.
34. Rack.
35. Height slide.
36. Height slide pinion.
37. Height scale pointer.
38. Height scale pointer screw.
39. Safety catch.
40. Steel guide.
41. Striding level.
42. Striding level nut.
43. Telescope.
44. Telescope trunnions.
45. Dew cap.
46. Objective ring.
47. Objective ring screws.
48. Horizontal collimating screws.
49. Vertical collimating screws.
50. Focusing screw.
51. Prism cap.
52. Eye end detaching screws.
53. Micrometer.
54. Micrometer screw.
55. Horizontal cross wire pinion screw.
56. Horizontal cross wire ring.
57. Horizontal cross wire screws.
58. Vertical cross wire plate.
59. Vertical cross wire screws.
60. Eyepiece.
61. Eyepiece adapter.
62. Electric lamp, 6 volts, 2 candle-power.
63. Lamp socket.
64. Lamp socket support.
65. Lamp shield.
66. Ground glass.
67. Mirror.
68. Brushes and contact rings.
69. Electric supply wires.
70. Plug to replace illuminating attachment.
71. Oil cups.

REMARKS ON DR. EDMOND HALLEY, (1656-1742.)

EUGENE FAIRFIELD MCPIKE.

The fact that progress in astronomical work depends largely upon familiarity with its annals, behoves one to peruse, if not carefully to study, the lives of those to whom the early development of the science is due. Dr. Edmond Halley's career is especially called to mind at this time because we are promised a return of his famous comet, in 1910, the moment of its perihelion passage being fixed upon by the late Count de Pontecoulant, as May 16.95 (Paris meridian time?) There are yet other reasons why we, in America, should be reminded of Halley's achievements, for, in 1698, King William III. appointed him to the command of the "Paramour," a Pink (?) with orders to make observations for the purpose of discovering the rules governing the variations of the magnetic needle. His commission continues in these words: "to call at his Majesty's settlements in America, and make such further observations as are necessary for the better laying down the longitude and latitude of those places, and to attempt the discovery of what lands lie to the south of the western ocean." To this venerable philosopher, therefore, belongs the distinction of being the first of England's scientific navigators.

Born near London, 8th November, 1656, during the Protectorate of Oliver Cromwell, Edmond Halley survived one of the most eventful periods of English history. His career was so closely interwoven with that of Newton that the biographer of the latter could scarcely pen the first page of his narrative without at least an implied reference to the former. Their united labors constitute the key-stone in the mathematical and astronomical history of the times in which they lived and that which has been builded since rests upon the same impregnable arch.

Associate member of the Royal Academy of Sciences (1729); *confrere* of Hevelius at Dantzig, of Cassini at Paris, of Abbe Nazari at Rome, and of the other principal mathematicians of Europe, Halley, having much traveled, was essentially a cosmopolitan in the world of science. At home in London he was "a man about town," popular with his colleagues and respected by those to whom chance had assigned a higher rank. He was a Gentleman in the English acceptation, for his family bore coat armor; he was a gentleman in that broader sense which implies much of scholarship, generosity and *bonhomie.* His sprightliness and constant gaiety, sources in part of his popularity, contributed to his success, which, however, was won by the most arduous and protracted labors. Space hardly permits a passing mention of any of his numerous discoveries and writings. The reader's curiosity in this respect will best be served by consulting Miss Clerke's admirable sketch of Halley in the Dictionary of National Biography. The story of the comet that bears his name would fill a book while an adequate account of his researches in terrestrial magnetism and his voyages connected with that investigation would occupy an even larger and more ponderous tome. The opinion seems almost universally to be held that Halley's greatest service to posterity lies in his publication of Newton's 'Principia' which, indeed, but for him, as Dr. Glaisher has said, would never have existed, for he not only sought out its immortal author and persuaded him openly to announce his demonstration of the law of gravitation, but actually saw the work through the press and generously defrayed the expense from his own scanty resources.

Halley lived to attain his eighty-fifth year and died at Greenwich, 25th January, 1742, leaving to his country and to the civilized world at large a priceless legacy. * * * * * * * No branch of human knowledge presents a grander vista nor deals more closely with the powers of Omnipotence than the science of the stars. The searcher of the heavens traversing the ethereal depths with no compass but analogy, has ofttimes a goal invisible. Fancy leads him, like Miller, to the center of that celestial galaxy of transcendent splendor whence the infinite

eye beholds worlds upon worlds, universes of universes all circling in perfect harmony.

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A SOLAR PROMINENCE.

J. B. COIT.

Upon Monday, May 23, at about $11^h\ 45^m$, E. M. T., while focusing the spectroscope upon Hα in the second spectrum, the slit being radial to the sun's limb, I noticed that which was at first taken to be a detached cloud floating clear of the limb. On turning the slit into the tangential position it was found that a bright arch reached from P=89° to P=100°. Sweeping with the slow motion, this arch was seen to be continuous throughout and strikingly symmetrical.

At the bases and along the entire curve, the formation was that of rather coarse *radial* filaments. The space beneath the arch was apparently entirely blank, under good definition, and the limb from 89° to 100° was in an essentially normal condition, remaining so to the close of the observation.

While making these sweeps, it was noted that the center of the arch was rapidly rising. A record of the phenomena was at once made and the slit was then narrowed to see if Hα was distorted. A somewhat hurried observation detected no displacement. At $11^h\ 55^m$ I began taking transits for altitude. Although the successive transits were taken without any pause, save to make the record, each one revealed a change in the altitude and in the general appearance. The first measured altitude of the highest point of arch was 90″, the form being still regular. The second altitude was 105″. After this it rapidly decreased, while the outline became irregular. The eighth and last transit at $11^h\ 58^m$ gave 70″. By this time, all semblance of the original form was gone and only scattered cloudlets remained. The last transit was taken upon the most elevated one of these, which seemed to excell the others in brilliancy.

At $12^h\ 1^m$ nothing could be found above the limb, while the chromosphere from 89° to 100° was quiet, save a few shreds where the bases

of the arch had rested. A five inch refractor showed no spots and no bright faculæ upon the eastern limb.

At the close of the observation it was estimated that the arch, when first seen, was one-half as high as when first measured and that the length of the filaments forming the arch was about one-third of the total central height. The rapidity of the changes after $11^h\ 55^m$ rendered it impossible to make any sketch or to set upon any line other than Hα.

The altitudes were, of necessity, determined by counting seconds and are, therefore, not highly accurate, but the error can not be great.
—Boston University.

THE TOTAL SOLAR ECLIPSE OF AUGUST 30, 1905.*

BY PROFESSOR W. W. CAMPBELL.†

The last total eclipse of the sun observed was that of May 17, 1901, whose path crossed the islands of Mauritius, Sumatra, Borneo and New Guinea. Its duration, in Sumatra six and a half minutes, was the greatest of any observable eclipse of the last half century. The shadow touched the islands at very few accessible points, and the choice of observing stations was unusually limited. Nevertheless, observations were undertaken by a relatively large number of well-equipped expeditions from this country and Europe. At nearly all stations clouds of various degrees of thickness covered the eclipsed sun and the work was seriously hampered by them. Fortunately many valuable photographs were secured through thin clouds. For example, Professor Perrine, in charge of the William H. Crocker Expedition from the Lick Observatory, obtained results of great value with each of his ten instruments, though only five to twenty-five per cent. of the light passed through the clouds. In fact, it would be difficult to say wherein they could have been better, except that the intramercurial planet search was incomplete in one-third of the area called for in the program.

A total eclipse, of short duration, occurred on September 20, 1903, in the southern Indian Ocean. The shadow did not pass over land, unless within the closed south polar continent, and no effort was made to secure observations.

A long eclipse will occur on September 9, 1904. It, too, will come and go practically unobserved, for its path passes eastward over the central Pacific Ocean without touching any known islands, and ter-

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†Director of the Lick Observatory, University of California.

minates on the coast of northern Chile about six minutes before sunset. With the sun at such a low altitude, the atmospheric disturbances and the almost complete absorption of actinic rays will preclude the possibility of securing satisfactory observations, except perhaps as to the general form of the corona. It is known that the Chilean astronomers are expecting to view the phenomenon. Further plans do not seem to be called for.

The next observable eclipse is that of August 30, 1905. It is well situated, and will be looked forward to with unusual interest. The shadow path begins at sunrise south of Hudson's Bay, enters the Atlantic Ocean a short distance north of Newfoundland, crosses northeastern Spain, northeastern Algiers and northern Tunis, passes centrally over Assuan on the Nile, and ends at sunset in Southeastern Arabia. The durations on the coast of Labrador, in Spain and at Assuan, are two and a half, three and three-fourths and two and three-fifths minutes, respectively.

It is none too soon to form plans for observing this eclipse. In this connection, an account of the leading eclipse problems now pressing for solution may have interest for the general reader, and perhaps some usefulness to those who will plan programs of work, though the latter will prefer a more detailed article than would be justified here.

There is probably no phenomenon of nature more beautiful and impressive than a total eclipse of the sun. Every such event is of great human interest. Even the uncivilized tribes of the earth realize, crudely, the force of the scientific fact that the sun is the origin of the light, heat and other forms of energy which make life on this planet possible.

The absorbing interest taken in eclipses by astronomers is on a broader basis. Our sun is one of the ordinary stars. In size it is perhaps only an average star; or it may even be below the average. It is the only star near enough to us to show a disk. All other stars are as mathematical points, even when our greatest telescopes magnify them 3,000-fold. The point-image of a distant star includes all its details, and it must be studied as a whole, whereas the sun can be studied in geometrical detail. Our sun is likewise the only star bright enough to supply metrical standards demanded in the study of other stars. It is not too much to say that our physical knowledge of the stars would today be practically a blank if we had been unable to approach them through the study of our sun. If we would understand the other stars, we must first make a complete study of our own star. Several of the most interesting portions of our sun are invisible, except at times of solar eclipse. Our knowledge of the sun will be incomplete

until these portions are thoroughly understood; and this is the reason why eclipse expeditions are despatched, at great expense of time and money, to occupy stations within the narrow shadow belts.

The difficulties of solar study, in spite of comparative nearness and intense brightness, are very great. It is not generally appreciated that we are unable to study the body of the sun except by indirect methods. The interior is invisible. The spherical body which we popularly speak of as the sun is bounded by the opaque photosphere—a cloud covering composed of condensed vapors of the metallic elements. The photospheric veil, including the larger interruptions in it which we call the sunspots; the brighter areas, closely connected with the photosphere, called the faculæ; the reversing layer, a few hundred miles in thickness, immediately overlying the photosphere; the chromosphere, a shell several thousand miles thick, associated with and overlying the reversing layer; the prominences apparently ejected from the chromosphere; and the corona, extending outward from the sun in all directions to enormous distances; these superlatively interesting features of the sun, constituting the only portions accessible for direct observation by telescope and spectroscope, are an insignificant part of its mass. They are literally the sun's outcasts. Our knowledge of the sun is based almost entirely upon a study of these outcasts. We might hope to reach safe conclusions as to the characteristics of a hermit nation by making a careful study of its banished subjects, provided the observed types correspond with types produced by our own civilization; but if new types, new customs, new forms, presented themselves, and were observable only at long range, our conclusions as to the characteristics of the country from which they were expelled would come slowly and uncertainly. It is a difficult matter to comprehend the structure and condition of any one of the sun's outcasts; the chromosphere, for example. To determine what the conditions within the body of the sun must be in order to create and maintain such an outcast shell is far more difficult.

The influence of eclipse observations upon solar and astrophysical research has been most remarkable. The reversing layer, the chromosphere, the prominences and the corona were in fact discovered at eclipses. Many of our present every-day methods of studying them are also eclipse products. The richness of eclipse results, considering the remarkably short intervals available for observation, is unique in science. To realize this, we need only recall that the durations of observable total eclipses, clear and cloudy, have amounted altogether to about one hour since the spectroscope was applied to the problem, and about half an hour since photographic methods have prevailed.

Eclipse problems relate not only to the properties of the less massive portions of the sun—everything, apparently, outside of the photospheric layer—but to the question of possible planets between the sun and Mercury. It is well known that mathematical theory, based upon Newton's law of gravitation, has not yet fully accounted for the motion of Mercury. The perihelion of its orbit moves forward at least 40″ in a century more than theory calls for. The most plausible way of accounting for this progression has been the supposition that an undiscovered planet, or a group of small planets, exists within the orbit of Mercury. The search for such objects has been a well-defined eclipse problem; the sun-lit sky prevents effective search by every-day methods. Organized efforts to discover such bodies by visual means were made at the eclipses of the late seventies and early eighties, but they were unsuccessful. Photographic methods, though not planned for efficiency in that particular problem, were applied in the nineties. Early in the year 1900 it occurred independently to Professor W. H. Pickering, of Harvard College Observatory, and to Messrs. Perrine and Campbell, of the Lick Observatory, that efficiency in the photographic method requires the cameras to be of relatively long focus, in order to reduce the intensity of sky illumination on the photographic plate; and each of these astronomers, unknown to the other two, fixed upon the proportions which such instruments should have. Their results were in good general accordance. The first attempt to apply this method was made by Professor Pickering at the eclipse of May, 1900, with camera lenses three inches in aperture and 135 inches in focal length, but no evidence was secured. Mr. Abbot, of the Smithsonian Institution party, obtained one photograph with a similar lens, covering a limited area of the sun's surroundings, which recorded eighth magnitude stars. Four suspicious images on the plates were noticed; but whether they were ordinary photographic defects or images of real objects could not be determined, as the required second plate of the same region was not secured by this party or others.

The last word on the subject is by Perrine, who applied the method in Sumatra in May, 1901. His four telescopes, making three exposures each, secured negatives in duplicate of a region 6° wide and 38° long—19° on each side of the sun, in the direction of the sun's equator. Through thin clouds covering two thirds of this area, one hundred and sixty-two stars, including several as faint as the ninth magnitude, were photographed; and through thicker clouds covering the remaining third, eight stars, four of them between 6.0 and 6.5 visual magnitudes, were recorded. While these instruments were in use in the preceding February at the Lick Observatory, exposures were

made on the region of the sky which would be occupied by the eclipsed sun in May. All objects on the Sumatra eclipse plates were recognized as known stars, by means of the February Mount Hamilton plates.

It is probable that any such planets would be well within the region covered, provided their orbit planes make a small angle with the sun's equator. The earth was very nearly in the plane of the sun's equator on May 18—exactly in it on June 3—which was a favorable circumstance. Again, there is little probability that such bodies would be as much as nineteen degrees from the sun, and a width of six degrees would therefore allow for a considerable departure of the orbit planes from the solar equator.

Professor Perrine has deduced the following interesting results from these observations:

"Before drawing any conclusions from these observations it is desirable to determine the relative brightness and size which any bodies in this region would have, by means of other members of the solar system. The asteroids seem to be best suited for this investigation, as they probably most nearly resemble the hypothetical intramercurial planet in size and condition of surface. The determination of the diameters of the four principal asteroids by Barnard [as below] renders these bodies the most suitable for such work.

Asteroid.	Visual Magnitude.	Distance, Miles.
Ceres	7.5	485
Pallas	8.5	304
Juno	9.5	118
Vesta	6.6	243
Arithmetical mean	8.0	290

The above magnitudes are those obtained at the Harvard College Observatory by photometric means. The results show such a wide range in albedo that the simple mean has been taken to represent the relations between magnitude and diameter for the group.

Assuming that the distance of the 'mean asteroid' from the earth is 153 million miles, we find that such a body, if transported to a distance of twenty-eight million miles from the sun (corresponding to an elongation distance of eighteen degrees), and seen from the earth at elongation, would be one hundred and ten times as bright. This corresponds to an increase in brightness of 5.1 magnitudes. Such a body would be relatively brighter near superior conjunction, and fainter near inferior conjunction. An intramercurial planet at the above mean distance from the sun would have to be only one tenth the diam-

eter of the mean asteroid to appear of the same brightness.

From the dimensions and brightness of the four brighter asteroids we find that on the average one of these bodies, three hundred miles in diameter, seen at the opposition distance of the mean asteroid, would appear as of the eighth magnitude. Hence an intramercurial planet of similar constitution and thirty miles in diameter should appear as a star of eighth magnitude. If the hypothetical planet were closer to the sun, the difference of brightness and size would of course be correspondingly greater than that found above.

These observations indicate, therefore, with the exception to be noticed later, that there is no planetary body as bright as 5.0 visual magnitudes within eighteen degrees of the sun whose orbit is not inclined more than seven and one-fourth degrees to the plane of the sun's equator. They further indicate that in two thirds of this region there was no such body as bright as seven and three fourths magnitude. The possible exception to be noted is that at the time of the eclipse such a body or bodies might be directly in line with the sun or with the brightest portion of the corona. The area covered by the moon's disk and corona was, however, less than one two-hundredth that of the region searched. Owing to the increased cloudiness at the end of totality, the search is not quite complete to the fainter magnitude, yet it seems altogether probable that were there any considerable number of bodies as bright as seven and three fourths magnitude, some of them would have been detected. A planetary body thirty-four miles in diameter would, under the conditions considered, appear as a star of seven and three fourths magnitude. The total mass required to produce the change observed in the orbit of Mercury is about one half the mass of the planet. It would require, therefore, no less than seven hundred thousand bodies thirty-four miles in diameter and as dense as Mercury to equal such a disturbing mass.

From the observations detailed above it does not seem possible that sufficient matter exists in the region close to the sun in the form of bodies of appreciable size to account for the observed perturbations."

Belief in the existence of intramercurial planets has been based upon anomalies in the orbital motion of Mercury, and Perrine's work has gone far to show that the discrepancies must seek some other explanation. Had the thicker clouds not reduced the *minimum visible* in one third the area observed in Sumatra from the ninth to the sixth magnitude, it is a question whether one could recommend that this search be continued at future eclipses. However, so long as we admit that it is a question, the effort to secure definite results, positive or negative, should be made. It is not impossible that existing bodies

could have been in the region of thicker clouds, or in that occupied by the moon and inner corona, or in areas outside the limits of the strip six degrees wide.

The eclipse of August 30, 1905, will occur when the earth is seven degrees from the plane of the solar equator. The maximum distance occurs September 7. It will therefore be advisable to search over a region of considerably greater width than was the case in 1901. Inasmuch as increased area means increased instrumental equipment, expense, and difficulty, a corresponding shortening of strip to be observed would perhaps be justified. It is to be hoped that observing parties well equipped for the intramercurial search will be located in Labrador, Spain, Tunis and Egypt. If clear weather prevails at any of the four stations very valuable results may be secured. Should a new planet be observed at three such stations, the enormous interest attaching to its discovery would be heightened by the fact that its approximate orbit could be determined at once. If no planets are revealed on first class plates, the negative result would be scarcely less valuable, though certainly less interesting, than positive results; and the intramercurial question would cease to be a pressing eclipse problem.

The sun's altitude will be only 26° in Labrador and 23° in Egypt. The altitude of the lower end of the area to be photographed will be small at these stations. The atmospheric disturbances and absorption at such low altitudes will require that the exposures be lengthened. Perhaps a better plan would be for the Labrador party to cover the entire critical region west of the sun, and only five or six degrees below it; and for the Egyptian party to cover the whole region east of the sun and only five or six degrees below it.

Eclipse observation of the sun itself concerns all that lies outside the photosphere and faculæ. While the main features of these outer volumes are for the most part quite irregular in form, yet in a general way they lie, going outward from the photosphere, in the order of reversing layer, chromosphere, prominences and corona.

The reversing layer was discovered at the eclipse of 1870 by Professor Young. It appears to consist of a thin stratum of incandescent gases, probably between five hundred and fifteen hundred miles in thickness, immediately overlying the photosphere. Its inner bounding surface seems to be quite definite and regular, but its outer surface is certainly not so. The depth of the stratum of vapor for each element composing it is probably a function of the properties and quantity of the element in question. The reversing layer is cooler than its substrata, yet abundantly hot, if isolated from its underlying strata, to produce a spectrum consisting of thousands of bright lines occupying

the positions of the dark lines of the ordinary photospheric spectrum. When the moon, at the eclipse of 1870, gradually covered the photosphere, the dark-line spectrum lasted until the instant when the photosphere entirely vanished, whereupon the reversing layer was isolated, and Young observed the sudden flashing out of its bright-line spectrum. A bright line apparently replaced each dark line, and lasted perhaps two or three seconds, until the moon entirely covered the reversing stratum.

In so complex a spectrum, lasting but a few seconds, visual observations were difficult, and no records of any considerable consequence could be made. The bright-line (flash) spectrum was photographed for the first time by Shackleton at the eclipse of 1896; and several photographs of it were secured at the three succeeding eclipses, but many were defective on account of poor focusing or other cause. They confirm Young's discovery of the reversing layer, which, by the absorption of its cooler gases, introduces the dark lines in the solar spectrum. The lengths of the arcs not covered by the moon also tell us much concerning the thickness of the vapors of the various elements, and therefore much concerning the structure of the sun at those levels. Additional work, with more powerful instruments, in perfect adjustment, is demanded, with a view to securing better quantitative results.

Photographs of the reversing-layer spectrum, made with two, four, or more seconds' exposure, are integrated effects. Changes taking place during the exposure are lost. For this reason, it would be very valuable if a continuous record of the spectrum at one point on the limb could be secured on a plate moving in the direction of the length of the spectrum lines. The writer obtained such photographs in 1898 and 1900, but with small instruments, not designed especially for that work; and it is hoped that improved apparatus will be available for the eclipse of 1905. There is need that flash spectra with both fixed and moving plates should be secured, since each system has its advantages and disadvantages. On moving plates the faintest lines might not be recorded, but a continuous record of changes in the strengths of lines, as the moon gradually covers the reversing strata, should be obtained.

The chromospheric stratum, overlying the photosphere, is of irregular depth, varying from four thousand to ten thousand miles. The reversing layer, to the best of our knowledge, is included in its lower strata. The prominences seem to be flame-like or explosive projections extending outward from the chromosphere; the matter in them previously and subsequently forming a part of the chromosphere. Many of the salient facts known about chromosphere and prominences were learned at eclipses; and they are still studied with some profit on such

occasions. However, the spectroscopic method of observing them, devised independently by Janssen and Lockyer in 1868, has made the prominences, and to some extent the chromosphere, available for every-day study. But it must not be overlooked that, while fairly satisfactory observations to one or both subjects can be secured without an eclipse, yet the eclipse negatives are still imperatively needed to show the mutual relations of the various structures—reversing layer, chromosphere and inner gaseous corona. It is known that the prominences are larger and more numerous at sunspot maxima than at other times. The question whether the chromospheric stratum is likewise thicker and more distorted at sunspot maxima than at minima is a question for eclipse observers to settle. Observations of the continuous spectrum of prominences or chromosphere can by present methods be made only at eclipses.

The corona, perhaps the most fascinating solar feature, is exclusively an eclipse phenomenon. Various attempts have been made to observe it visually, photographically and thermally, without an eclipse; but all failed, and there seems to be no hope of success by methods now known. Any chance for even moderate success would seem to be limited to the inner portion whose spectrum contains bright lines. A daily record of this would, no doubt, be extremely valuable, but the real problem of the corona would remain unsolved.

In many respects the corona is as enigmatical as ever. A coronal photograph is the result of a projection upon and into one plane, at right angles to the line of sight, of all that remains of the sun after subtracting the volume of matter hidden by the moon. The tops of some coronal streamers, the intermediate portions of others, the bases of those near the limb and the corresponding parts of prominences and chromosphere are all projected into one point. Whether every man who has gone forth to solve the riddle of the corona has fully realized the odds against success is doubtful.

Much has been written concerning a possible eruptive origin, or about magnetic influences in shaping the forms of its streamers. It has been shown that the details of the corona at one eclipse are totally different from those at another and that the outline form of the corona is a function of the sun spot cycle. At sun spot maximum the general form is nearly circular, and the polar streamers are nearly as bright as the equatorial streamers. At minimum, the polar streamers are much fainter than the equatorial ones, and long wings seem to extend out approximately from the spot zones. It is a surprising fact that, with all the changes of form, we do not yet know whether the materials composing the streamers are moving in, or out, or both, or neither.

The epoch-making, large-scale coronal photographs by Schaeberle in 1893 opened a promising way of determining such facts, but astronomers have been slow in taking advantage of the opportunity. Photographs of the corona should be secured for this purpose at widely separated stations—preferably at three or more stations—with essentially identical instruments, and with equivalent exposures, in order that results may be as nearly comparable as possible. This effort to determine motion in the corona, it seems to me, is the most important problem of the coming eclipse; and, fortunately, the circumstances of widely separated stations in Labrador, Spain, Tunis and Egypt, and promising weather conditions at the last three are favorable for the attack. Considering all elements of the question, including that of probable unsteadiness of the atmosphere at one or more stations, the five-inch aperture, forty-foot focus cameras, promise the most directly comparable, and therefore the best, results. The only case of motion on coronal plates thus far observed seems to be that detected by Schaeberle, on the Chile-Brazil-Africa plates of 1893; and in this instance the moving mass was decided to be a comet, and not a part of the real solar appendage.

One of the most intensely interesting features ever observed in the corona was the tremendous funnel-shaped disturbance recorded on the Sumatra plates of 1901. Perrine was able to show, with essentially no room for doubt, that the vertex of the disturbance was immediately over the large and only sun spot visible on the sun in the week preceding and the week following the eclipse. The circumstances were unusually favorable for reaching this conclusion: there was but one sun spot; it was very near the limb at the time of the eclipse; there was but one region of unusual disturbance visible in the corona; this was on an extraordinarily large scale, and its vertex was near the sun's limb; and the disturbance and the sun spot had identically the same position on the sun's limb. It was exceedingly unfortunate that three cameras of the forty-foot pattern could not have been working in harmony, at three stations widely separated, to determine what changes, if any, were taking place in the disturbed coronal area. Under excellent atmospheric conditions, cameras still larger than those referred to should record more minute details of coronal structure, and thus lead to valuable results; but such observations would reach their full value only in case comparisons could be instituted with photographs taken under similar conditions at distant stations. However, as already stated, cameras of the forty-foot pattern give greater promise of co-operative usefulness, taking into account the average atmospheric conditions which must be expected at some of the stations.

The spectra of recent coronas have led to most interesting results. They leave no doubt that, at those eclipses, the spectrum of the inner corona contained no perceptible dark lines. Perrine's Sumatra photographs seem to establish that the spectrum of the great outer portion is substantially a copy of the solar spectrum. The simplest interpretation of these observations is that the outer corona is largely composed of minute particles which reflect and diffract the sunlight falling upon them, whereas the portions near the hot solar surface are most incandescent, shining by their own light. Polarigraphic observations are in harmony with this theory. Opposed to the idea of the incandescence of the inner corona stands, alone, the thermographic observations by Abbot in 1900, of a corona less hot than the instrument with which he worked. While it is difficult to assign such a low temperature to particles near the solar surface, and one should perhaps look for other interpretations of the thermographic results, yet there is an urgent demand for a repetition of all the preceding observations bearing upon the nature of the corona.

The polarigraphic observations of recent coronas have been very interesting—leading to the knowledge that the light of the corona is strongly polarized, except, apparently, in close proximity to the sun's surface; and strengthening the view that the corona is very largely composed of minute particles of matter which receive their light from the photosphere. Unfortunately, the photographs do not permit the making of quantitative measurements of the amount of polarization in and across the solar radii; and future programs for eclipse observations in this line should make provision for securing comparable unpolarized coronal images for standards of reference.

Special interest will be taken in determining whether the comparatively shallow inner stratum of the corona which yields a bright-line spectrum, is more extensive at the sunspot maximum of 1905 than it was at the minimum of 1898-1901. The chances are that it will be both thicker and more uniform in thickness. Should it be brighter than at recent eclipses, the opportunity to search for new coronal bright lines will be excellent.

The accurate wave-length of the principal coronal bright line, near λ 5303, should be determined. A modern spectrograph, holding three dense flint prisms, should make the problem easy. The accurate wave-lengths of all truly coronal lines should be determined as rapidly as possible, partly in order that a serious effort may be made to represent them by a simple common law, as has been done for hydrogen and helium.

Of many other eclipse problems—the photometry, the shadow bands,

etc.—it need only be said that accurate observations will prove very useful.

The tendency of recent eclipse work is toward a unification of the problem. The main divisions of the sun's structure are no longer to be studied separately. Close connection has been observed between spots and faculæ; between photosphere and reversing layer; between sun spots and coronal disturbances; between coronal streamers and prominences; between prominences and chromosphere; between the sunspot curve and the form of the corona; and in other ways the unity of the problem is emphasized. This is only what we should expect, for all these outward and visible features of the sun must be related products of the stupendous forces at work within its body. In reality, all observations of the sun, whether those made daily at fixed observatories or those secured at eclipses, bear upon the solution of one problem: the structure, composition and condition of the sun, from its center to the outermost limits of the coronal streamers.

It is well known to eclipse observers that a regrettably large proportion of observations of these phenomena are failures, or are but partially successful. Some of these unfortunate outcomes are due to nervousness at the critical moment; a psychological state of which some observers knowing nothing, and against which others are unable to contend. It is a mistake to invite nervousness by attempting to do too much in the limited duration of totality. If seven photographs can be secured with one instrument, working with moderate speed in changing plates, an attempt to secure eight by working under high nervous tension would be a serious error. However, the most prolific source of failure is that of new instruments and new methods used for the first time on eclipse day. It is not an uncommon practise to delay preparations until a few months or weeks before expeditions must depart for their stations; to order new instruments, or new parts of instruments, just in time to have them shipped from factory to station; and to leave insufficient time for the rehearsal of program after the instruments are in supposed adjustment. It is unnecessary to say that this is culpable management and all wrong. Every piece of apparatus should be set up, adjusted, tested and used at the home station; and time should be available thereafter for making modifications in apparatus, methods and program, and for retrial. With every possible preparation made before leaving home, the astronomer will find his time occupied at the eclipse station in solving the ninety and nine local problems whose coming is sure, but whose nature can not be foreseen. To install half a dozen instruments in a fixed observatory so that they will work satisfactorily, one at a time, and at the observer's leisure, is not a

small problem. To construct a temporary observatory in an out of the way corner of the earth, to mount the eight or ten instruments, and to train the dozen or more assistants so that all the instruments and all the men will work together satisfactorily at the fixed instant of totality, is a problem of a very different order. The point which I wish to emphasize is that preparations for observing the eclipse of August, 1905, should begin early in 1904.

ECLIPSE EXPEDITION IN 1905.

MARY PROCTOR.*

In the Journal of the British Astronomical Association for April, 1904, a report is given of a meeting of the Association, held on March 5, 1904, Mr. G. F. Chambers made some very interesting remarks with regard to the coming eclipse of August, 1905, the pathway of shadow crossing Labrador, Spain, Algeria, Tunis, Tripoli, and north-east of Assouan, Egypt. With regard to Spain, he had been making certain inquiries as to Spanish summer weather, and had been in correspondence with Senor Iniguez, the Director of the Madrid Observatory.

The line of central eclipse crosses Spain diagonally from northwest to southeast, and with regard to climate the north coast was particularly promising and satisfactory in the month of August, though it was the hot weather month. There was a table land in the northern part of Spain, within easy reach of the town of Burgos, which he was told offered many advantages, being away from the coast and with less risk of fogs, and altogether a pleasanter and healthier climate for a sojourn in the month of August. The town of Burgos was the best actual geographical centre for access to all parts of the central line. It was a large and important city of great interest, both historically and architecturally, and would probably be the gathering ground of a great number of astronomers going to Spain from all the countries of Europe.

On reading these remarks, the idea occurred to me, that an exceedingly pleasant and delightful trip, combining science and pleasure could be made, by the following arrangement. Every summer private parties leave this country for Europe, about the first week in July, remaining until August or September. . In this case, a private party is being organized to leave Boston July 1st, 1905, by the White Star steamer "Canopic." After a trip through Italy, Switzerland, Ger-

*For further information and circulars, address Miss Mary Proctor, 141 West Forty-seventh Street, New York City, N. Y.

DR. ISAAC ROBERTS

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many, the Rhine, Belgium and France, we are planning to take a side-trip to Burgos, for those who are interested in observing the total eclipse of the sun.

We shall leave Paris a few days prior to the eclipse, arriving in Burgos in time to select observing station and make necessary preparations for the event. Leaving Burgos the evening of August 30th, we return to Paris via Bordeaux and complete our trip by a few days' sojourn in England, Ireland and Scotland, returning to New York September 18th.

DR. ISAAC ROBERTS, F. R. S.

W. S. FRANKS.

Astronomical photography has lost one of its greatest and most successful exponents in the person of the late Dr. Isaac Roberts, who was stricken down with tragic suddenness on the 17th of July whilst yet in the zenith of his fame and mental powers. A brief sketch of his career, by one who has been closely associated with him in his scientific work for the last twelve years, may be of some interest to the readers of this journal.

Born at Groes, Deubighshire, North Wales, on the 27 of January, 1829, Isaac Roberts, when only 6 years of age, came with his parents to reside in Liverpool. The only education he received, up to his fourteenth year, was obtained partly by his father's teaching and in the elementary schools of that time, especially one of the Welsh Calvanistic Sunday Schools, with which he was connected. He retained his knowledge of the Welsh language in after life, speaking and writing it fluently. At the age of 14 he was apprenticed to a builder and contractor, and learned his business so thoroughly that he afterwards became president of the Master Builders' Association, and a consulting expert in all matters relating to the craft. Though working thirteen hours a day, he yet found time to attend the evening classes at the Mechanic's Institute and elsewhere, and laid the foundations of that taste for scientific pursuits which was afterwards to bring him honor and renown. As a result of unremitting attention to business, he amassed a considerable fortune; and, whilst still remaining a partner in a large contracting firm, he was now free to indulge in scientific work, for which he had so strong a leaning. Geology was the subject which then claimed him as its votary; his first paper, on the Wells and Water of Liverpool, appearing in 1869, and in the following year he was elected a Fellow of the Geological Society. But he also paid

considerable attention to chemistry, electricity, microscopy, spectrum analysis, etc.; and took a leading part in all scientific matters in the city, where he was a well known and respected citizen. In 1878 he read a paper before the British Association on the filtration of sea water through triassic sandstone; and from 1882 to 1889 carried out a series of elaborate experiments on the movements of underground water in the vicinity of Liverpool, as affected by barometric pressure, and the attraction of the Sun and Moon. Another piece of work which he carried out successfully was to determine the vertical and lateral pressures of granular substances, such as corn, sand, shot, etc., when stored in cells up to 80 feet in height (as required at the docks); and this necessitated specially devised and ingenious weighing machines. The results were published in the Proceedings of the Royal Society for January, 1884. However, he now began to develope a taste for Astronomy, and in 1878 erected a 7-inch refractor at 26 Rock Park, Rock Ferry—the same house which Nathaniel Hawthorne occupied when American consul in Liverpool. Afterwards, at Maghull, seven miles north of the city, he turned his attention seriously toward celestial photography, commencing with an 18-inch reflector—which he subsequently presented to the Observatory at Dunsink, Ireland. Then he ordered a 20-inch reflector from Sir Howard Grubb, to whom he entrusted the task of mounting it on the same equatorial stand as the 7-inch refractor—one telescope acting as the counterpoise to the other, a combination which has since received the name of the "Twin Equatorial. Each telescope has independent motion in declination, whilst the clock movement in right ascension is common to both. Over a year was spent by Dr. Roberts in minor alterations and perfecting details, before the instrument could be considered good enough to satisfactorily perform the work which was expected of it. From that day to this—with the exception that a Calver mirror was substituted for the Grubb in 1888, and a 5-inch Cooke camera added in 1895—the equipment remains the same as originally planned by Dr. Roberts; a fact which speaks for itself as to the patient forethought bestowed upon this pioneer instrument, which has now become historically famous. In 1885 was planned the first systematic photographic work with the 20-inch reflector, which was the herculean task of photographing the whole of the northern heavens, on a scale twice that of Argelander's well-known maps. Beginning at the North Pole, considerable progress was made with this work; when, at the instance of Sir David Gill and the late Admiral Mouchez, the International Photographic convention was held in Paris, to discuss the advisability of charting

both hemispheres by the coöperation of the leading public observatories. Dr. Roberts attended this meeting; and, seeing that the work was about to be undertaken on so imposing a scale, wisely relinquished his share in it, and turned his attention to the photography of star clusters and nebulæ—for which the reflector was singularly well adapted. Even at this time, he had already recognized the perishable nature of the gelatine film of the modern dry plate; and, with his accustomed perseverance and mechanical ingenuity, he devised a costly instrument for engraving directly upon copper plates the stars shown on the glass negatives. This instrument, which he called the "Stellar Pantograver," was made by the late Adam Hilger, and it is absolutely unique of its kind. It was really a combined measuring and engraving machine; and, though it was only adapted to engrave stars accurately to scale, and could not, of course, delineate such objects as the nebulæ; it has latterly proved serviceable for the purpose of measuring the condensations in certain nebulæ—a work on which Dr. Roberts had been engaged for several years. After a few years' experience of the climate of Maghull, it was found to be unsatisfactory for the delicate work of photographing nebulæ; and, accordingly, as the result of much diligent inquiry, the instruments were dismounted and re-erected in a new observatory on the summit of Crowborough Beacon, in Sussex, at an altitude of 800 feet above sea level, and commanding magnificent views of the surrounding country. This, then, is the "Starfield" Observatory, whose products are so widely known in the astronomical world, and it probably occupies the finest site to be found anywhere in England. Here, for the last thirteen years, the photography of clusters and nebulæ has been steadily pursued; thousands of valuable negatives being stored as the result of this persistent labor. When leaving Liverpool for Crowborough in 1890, Dr. Roberts was presented with an address, signed by the Mayor and chief citizens of that place, as a parting mark of the esteem in which he was held—both as a public man and a student of science. In the same year he was elected a Fellow of the Royal Society; and two years later the University of Dublin conferred upon him the degree of D. Sc., on the occasion of its tercentenary. In 1895 he was awarded the gold medal by the Royal Astronomical Society (of which he had been a Fellow since 1882) in recognition of his unique and valuable contributions to astronomical science. He has published two quarto volumes of "Photographs of Stars, Star Clusters and Nebulæ;" Vol. I being issued in 1893, and the second volume in 1899. Copies of these works were generously distributed by their author to most of

the public observatories and libraries throughout the world. Besides these portly volumes, Dr. Roberts contributed some twenty-seven articles to "Knowledge," between the years 1895 to 1903; most of them illustrated by full page collotype plates. And in the "Monthly articles to "Knowledge," between the years 1895 and 1903; most of are no less than thirty-five pages credited to him, besides thirteen annual observatory reports. It was his intention to publish a kind of index to all his published papers, with short précis of each; in fact the material for it was compiled by the present writer only a short time ago, but it remains in manuscript at present.

As a man Dr. Roberts was of a somewhat original type of character; caring little for orthodox theories, and preferring his own methods of investigation. Of patience and perseverance he had an unlimited supply, and there were few difficulties which could not be overcome by him. He was very ingenious as a mechanician, and many a professional expert would have been proud of his fertility of resource. In devising new experiments he had few equals; the idea was worked out on paper, and nothing remained but to reduce it to practice. He was a generous friend, as those who knew him intimately would say; and a gap is left, which will be hard to fill. But his *work* will live; and posterity judges of a man rather by his work than by any eulogies carved upon his monument.

THE ENDOWMENT OF ASTRONOMICAL RESEARCH II.*

EDWARD C. PICKERING.

In order to attain as great an advance in astronomical research during the twentieth century as in the nineteenth, careful plans must be made for its endowment. The same skill in organization, combination of existing appliances, and methodical study of detail, which in recent years has revolutionized many commercial industries, should produce as great an advance in physical sciences. Astronomy in particular, through the striking progress it has made during the last half century, and its appeal to the imagination, has received more liberal aid than almost any other science. This has enabled astronomers to develop well organized observatories, and to carry on large pieces of routine work. They are therefore especially fitted for undertaking researches on a scale that will constitute a real advance. It is the object of the present pamphlet to show how this work can be carried still further,

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how the quality of the work can be raised to a new plane, and how a large or small sum of money may be expended so as to obtain the best results.

There are seven methods by which Astronomy can be aided, each of which may be considered in turn.

1. *Fellowships for Astronomical Students.*—A large sum of money would not be required for this purpose. Ten fellowships, each yielding annually $500, would probably be sufficient. They should be used for students especially interested in Astronomy, proposing to make it their profession, and showing a capacity for original research. The successful candidates should be sent to universities where special courses in advanced astronomical work are given. It is not desirable that there should be too many such fellowships, since the number of permanent positions for astronomers is limited. This difficulty is partly remedied by No. 7, described below. A large part of the expenses therein contemplated will be for personal services, and as work of the highest grade will be demanded, it is only fair that suitable salaries should be paid. The future of Astronomy will depend largely on giving a proper preparation to the men to whom the most important equipments will be intrusted.

2. *Astronomical Expeditions.*—Large sums of money have been wasted in sending out expeditions, in charge of incompetent persons, to observe Total Eclipses of the Sun. If the weather is cloudy at the time of the eclipse no result is obtained, if clear, the newspapers at once announce that a great success has been attained, and results secured which may prove of vast scientific value. In many instances; nothing further is ever heard of such work. The real addition to our knowledge of solar physics during the last thirty years, from such expeditions, considering the money expended upon them, is discouragingly small when compared with what might have been obtained by a more judicious expenditure of the same amount of money at a fixed observatory, where some results of value would surely have been obtained. It is often said that a discovery of so great importance may be made that it would compensate for their entire outlay, but this applies with equal force to almost any other plan of work. The fact that a government or individual will often make the appropriation desired for a special expedition, and would not make it for other astronomical work, in no way lessens the responsibility of those who ask for such aid.

Undoubtedly, every eclipse should be photographed by at least one skillful observer, and especial pains should be taken to solve particu-

lar problems, as the existence of an intermercurial planet, sudden changes in the corona, etc. The best method for securing results of real value appears to be that adopted by the English astronomers. A permanent committee is appointed which attempts, year after year, to solve certain problems of great importance. The experience gained during each eclipse aids later expeditions. Government assistance is often obtained in sending warships. Even then, the expenses are likely to be very great, and clouds may cause entire failure. If, therefore, good photographs are obtained, neither time nor money should be spared in making a careful examination and discussion of them.

3. *New Observatories.*—A new observatory of large size should only be established after careful consideration. The gift of a large telescope, to a university unprepared to receive it, is often worse than useless. Not only can no work of much value be done with it, without a large annual expenditure, but the existence of large telescopes which are idle discourages other donors who see that there is no return for the great outlay. For teaching purposes, a telescope of 8 to 12 inches aperture and a 3-inch transit instrument are large enough. The best work in observation can never be done except when the atmospheric conditions are excellent, and this would seldom occur near a university or large city. On the other hand, a fruitful field is open in the application of photography to a very large reflector, but the best possible location, preferably in the southern hemisphere, as in South Africa, should be chosen. Such an instrument would be of little value unless means were provided for keeping it at work, and for discussing and publishing the results obtained.

There is one class of astronomical institution, a computing bureau, which might be established to great advantage at a large university, where work of the kind proposed was already in successful operation. At one institution the work undertaken might be the measurement and reduction of photographic plates, and at another the computation of orbits of comets and asteroids. An astronomer particularly successful in photographing the stars might find on his plates the trail of an asteroid of great interest, like Eros. Such an observation would be of no value unless he measured its position and, after taking additional photographs, determined its orbit. This he would do to great disadvantage compared with those who devote their entire time to such work, and could easily procure additional assistants as required.

4. *Publication.*—The cost of publishing many important investigations is too great to be provided for by existing periodicals. Means

ought to be supplied so that no really good work should fail to reach the public for this reason. Provision should also be made for lengthy memoirs, the cost of which is sometimes very great, since they include extensive tables, or require elaborate illustration. The work of deceased astronomers, when of sufficient value, should also be promptly completed, reduced, and published. Probably the Astronomisches Gesellschaft and the Royal Astronomical Society would expend money to great advantage in this way.

5. *Aid to Working Astronomers.*—There is no way in which a more prompt and effective return can be obtained for a moderate outlay than by grants to astronomers qualified to expend them. The replies to the Circular of 1903, described below, and also to the Bruce Circular of 1890, show this very clearly. The number of good applications from German astronomers is particularly large. The sum of $10,000 would permit from ten to twenty valuable researches to be undertaken at once. Many of the ablest astronomers in Europe, and in this country, are obliged to devote nearly all of their strength and energy to teaching. In many cases, their interest is so great that they would gladly give much of their own time to researches of the greatest importance if, by a grant of a few hundred dollars, they could obtain the needed instruments, or employ assistants or computers. A donor could thus obtain, at a trifling expense, the services of some of the most eminent astronomers in the world, in expending his gifts. Care should be taken to make the restrictions as light as possible. A man of genius, in many cases, cannot work at all, except in his own way, and at his own time.

6. *Aid to existing Observatories.*—Several of our large observatories have now the appliances for a greatly increased amount of work. Large sums of money could be expended for salaries of additional assistants, for publications, buildings, instruments, etc. As the executive organization is already provided, the returns from additional gifts should be very great. Many of the most important advances to be expected in astronomy will be obtained from large pieces of routine investigation. Astronomers having learned the best methods of determining the position, motion, brightness, spectrum, and other properties of a star, should be prepared to apply them to great numbers of similar objects. Generally, the person who devises a new method is not the one best qualified to superintend a large corps of assistants, and to carry out an extensive routine investigation which may occupy many years.

7. *International Coöperation.*—This is probably the most import-

ant problem of all, and that most likely to lead to a real advance in astronomical science. The best illustration of the work contemplated is the determination, under the direction of the Astronomisches Gesellschaft, of the positions of northern stars of the ninth magnitude and brighter. A committee of experts should hold lengthened meetings and discuss plans in detail. It might be best to publish a provisional plan and invite criticism before beginning work. The observations should then be divided among those best qualified to make them, leaving to each observer greater or less freedom in carrying out the work. Preliminary observations would probably show which was the best method, and it is difficult to see why, in routine work, all should not conform to that. In determining a single quantity, like the solar parallax, of course the greatest variety of methods possible should be used. The reductions, publications, and discussion should be made by those best qualified, and not necessarily by the observers.

As an example of the method of procedure, we may suppose a Committee appointed who would first consider in turn, and in detail, the present needs of each department of Astronomy. The answers to the Circular described on page 11, give the views of the leading astronomers of the world, on this question. For instance, in considering the measurement of double stars, they would correspond with all astronomers now engaged in such observations. They would decide whether an undue, or an insufficient, amount of time and energy was directed to this work. They would then attempt to induce observers to adopt the best methods of measurement, and would supply micrometers of the most approved form, when needed. Observers displaying especial skill might be furnished with recorders or assistants who would learn their methods. In discussing orbits of double stars, complaint is often made that certain stars are neglected while a needless number of observations is made of others. If the subject was being neglected, an appropriation might induce a competent observer to take it up. All these difficulties could be reduced or avoided by proper organization, or, when necessary, supervision. The one object would be to secure the greatest scientific return for the given expenditure, and to avoid the reproach of the astronomer of the future, who may say that present opportunities have been neglected.

While a large sum of money, the equivalent of that required to establish an observatory of the first class, would be needed to carry out this plan in full, it will be seen that a moderate amount would permit a portion of it to be tested. The immediate expenditure of \$50,000 to \$100,000 would show results that would amply justify a

larger outlay. Very different ends would be attained by the different methods. Thus, No. 1 is educational, and insures the efficiency of the astronomer of the future, No. 5 aids the individual man of genius, while No. 6 and especially No. 7 undertake to solve the great problems now before us, and to advance the science to a new and higher plane.

The organization required to carry out this plan must next be considered. It may be divided into two parts, the care of the principal, and the expenditure of the income. The first of these is easily provided for, and if the amount is large may well be left to the donor. Permanency, a relatively high rate of interest, and certainty that the wishes of the donor will be fulfilled are three essentials. The expenditure of the income is a more difficult matter. If intrusted to an international committee, frequent meetings cannot be held, and correspondence is slow and unsatisfactory in many cases. Such a committee, however, would be able to discuss problems from the broadest standpoint, and would be the best judge, in international work, of what part each country should undertake. A local committee could meet frequently and secure the active interest of several persons, but it could not consist of experts who would have a good technical knowledge of the researches to be undertaken. A national committee would occupy an intermediate position, with some of the advantages, but unfortunately some of the disadvantages, of both. The experience of the writer is that all the work of such a national Committee is likely to be left to one man, and even if well attended meetings are held, it often happens that the wishes of the most aggressive member, and not the combined opinions of all, are carried out.

On the whole, the following plan is recommended. The appointment of a local committee consisting of men interested in Astronomy but not necessarily familiar with its technical details. Investigators in some department of science, and men of affairs qualified to judge of other men, and of the work done by them, should be selected. With the proper machinery to collect the views of experts, such men could easily carry on successfully the first six of the methods described above. As a parallel case, the Board of Trustees of a University can select the best man for a Professor of Sanskrit, or with expert aid can organize a technical school, although as individuals their knowledge of either subject may be very slight. The duties of this Committee would be, first, absolute fairness. They should spend the income so as to secure the greatest scientific return, and should be wholly independent of all personal considerations, and of all local conditions. Secondly, their work should be active, not passive; they

should try to spend the income, not to preserve it. Whenever an unusually able memoir was prepared by an astronomer hitherto unknown, they should make a business of learning his needs, what he would require to carry his work still further, and if possible induce him to undertake better or more extensive researches. In many cases, they could excite local interest and could secure aid for him from the friends of his Observatory, who might not otherwise know how important it was that his work should be aided. When a grant was made to an astronomer he should be made to feel that, in accepting it, it is he who confers the favor. He aids the Committee in securing better results for their expenditures than they could otherwise obtain. Many astronomers are unwilling to ask for aid, owing to modesty, to motives of delicacy, or from fear that the results will not be considered adequate. If the members of the Committee are satisfied that the object is a good one, they must take the responsibility of success or failure. In many cases, they must ask advice of experts, in some cases they must employ them to investigate, or to try preliminary experiments. Often a preliminary appropriation should be made, its continuance or increase depending upon the results attained.

The seventh method described above stands on a wholly different basis from the others. Here the work must be done by experts, the greatest specialists in their departments. Many important investigations have been undertaken by international societies, and such work could be greatly increased if large sums of money were at their disposal for this purpose. As this is perhaps the greatest problem in Astronomy it might seem presumptuous to discuss it further here.

A brief description of the attitude hitherto maintained by this Observatory, to other astronomers, is given below, and may explain its present policy in this matter.

One of the objects of the Astronomical Observatory of Harvard College, as stated in its Statutes (Annals, Vol. I, p. lix), is "in general, to promote the progress of knowledge in Astronomy and the kindred sciences." Various examples of the attempts to carry out this plan, by coöperation, publication of work done elsewhere, and in other ways, will be found in the Annual Reports and Annals.

In 1886, a definite attempt was made to secure the sum of $100,000, the income to be used in aiding other astronomers, and a pamphlet was published describing this plan. Four years later, Miss Catherine W. Bruce gave the sum of $6,000, to show what results could be obtained in a single year. This appropriation was distributed among fifteen astronomers, eight in Europe, one in Asia, one in Africa, and

in North America.

The next attempt made by the writer was in 1901. It was thought that a Committee representing the principal Research Funds of the country might render them more effective, and secure harmony in the expenditures of the money now available. Also, that a loeal Committee could do more work than an international or even a national one, since more frequent meetings could be had. Delegates were therefore appointed by the Rumford Committee of the American Academy, and by the Trustees of the Elizabeth Thompson Fund. The Acting President of the National Academy agreed to attend the meetings unofficially. The members of the Committee thus formed, the writer being also included, believed that a larger committee would render the work more effective. Additional members were invited, but no results were obtained.

Other plans were at once prepared, when the establishment of the Carnegie Institution entirely altered the prospects for original investigation in science in the United States, and rendered it probable that the immediate needs would be supplied from this source. No provision, however, has thus been made, so far as the writer is aware, for general aid to astronomers in other countries.

In April, 1903, a pamphlet was published showing how a large sum of money could be usefully expended each year for extending astronomical research. It was stated that much better results could be obtained by coöperation, avoiding duplication of work, providing astronomers with assistants and other means for undertaking neglected investigations, furnishing the means of employing the many large telescopes now idle, and, in general attempting to improve the present quality and quantity of work done, regardless of individual or country. It was further proposed that the fund should be administered by a committee of astronomers, wholly unselfish and unprejudiced, the only object being to secure the greatest scientific return for the expenditure, and that Harvard should act as trustee of this fund, on the ground of its security, permanency, and success as an investor, and since the desire to aid astronomers throughout the world has not been made a part of the policy of observatories elsewhere.

A circular of inquiry was then printed and sent to all the members of the Astronomisches Gesellschaft, and of the American Astrophysical Society, to about two hundred members of the Royal Astronomical Society, and to a few others. It is believed that few astronomers widely interested in the progress of science, and whose opinion would be of much value, were thus omitted. The replies to this circular

were very instructive and valuable, and I take this occasion to thank my friends for the trouble they have taken in the matter.

The following five questions were contained in the circular:

1. How do you think money could be spent most advantageously on Astronomy at the present time?
2. Can you recommend any definite plan, in form for presentation to a possible donor?
3. In what way could money be most usefully expended at your Observatory, or under your direction?
4. Can you give (not for publication) the names and addresses of any persons who are interested in your Observatory, and who are able and might be willing to aid it, if the matter were properly presented to them?
5. What improvements do you suggest in the plan proposed for the Endowment of Astronomical Research?

A discussion of the replies to questions Nos. 1, 2, and 3 would be given here, but it is believed that the writers would prefer a postponement of such action, until the establishment of a fund would enable a part at least of the proposed work to be undertaken.

Question No. 2 should have followed No. 3, as it was intended to refer to either Nos. 1 or 3. It was hoped that plans would be sent which could be enclosed in the letters proposed below, in discussing No. 4. If a large sum of money were already available, many definite plans would doubtless have been presented. The answers to No. 2 were in some cases covered by Nos. 1 or 3.

But few answers were given to question No. 4. I had hoped that an influential Advisory Committee could render important aid through this question. If the members were satisfied that an astronomer was doing excellent work and needed money for an important investigation, they could call the attention of the friends of his Observatory to the matter very effectively. In many cases, an astronomer would hesitate to do this himself, and the opinion of unprejudiced experts ought to have a weight that would not attach to the views of the individual concerned. I should be very much gratified if astronomers considered the work of the Harvard Observatory so important that they would take such action regarding the additional work I wish to undertake.

An excellent suggestion in reply to question No. 5 was made by Mr. A. R. Hinks of the Cambridge Observatory, England. He recommended the publication of proposed forms of investigation, in order to secure the criticism of astronomers before, instead of after, it is too late to alter them. This seems to be especially important in the case of large pieces of routine work.

Few improvements or criticisms of the plan were suggested by foreign astronomers. One or two advised that the Committee should be international, but probably the general feeling was that, as it was hoped to collect the funds in the United States, it was only fair that they should be controlled by Americans.

Among American astronomers, however, strong objections were made to the part it was proposed that Harvard should take in the plan. For this reason, two leading astronomers declined to serve even on an informal Advisory Committee. It was explained that this objection did not arise from jealousy of Harvard, or from fear that the plan would not be well carried out there, but from a belief that one observatory should not be more prominent than another in such a scheme, and that the control of such a fund and of its expenditure should be wholly independent of any one institution. I believe that the selection of a trustee for the care of the proposed fund should be made by the donor, and had expected that the informal Advisory Committee would have recommended some method of appointing the final Committee, which would have secured unprejudiced action. The function of the first of these Committees would have been to propose a plan like that described above. This want has been supplied, in a great measure, by my friends, Mrs. Henry Draper, Major E. H. Hills, Professor Simon Newcomb, and Professor H. H. Turner, to whom I am indebted for important suggestions in preparing this pamphlet.

There are certain advantages to be gained by throwing the responsibility upon a single individual or institution, as all mistakes or failures can then be located and remedied. Continued efforts will accordingly be made by the writer to accomplish the desired results. As other observatories have not expressed a wish to aid astronomers elsewhere, there seems to be no objection to making it a part of the policy at Harvard.

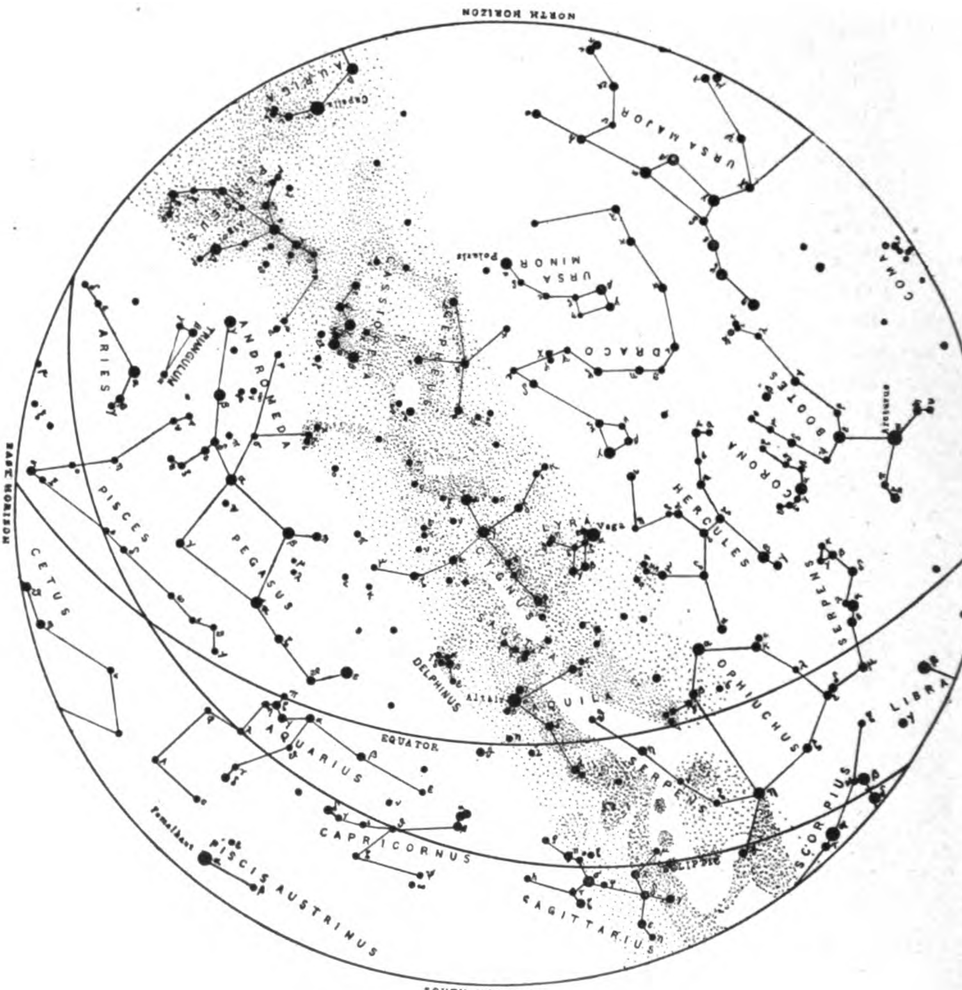
The present pamphlet has been published to supplement that issued in 1903, a copy of which will be sent to those who desire it. It is believed that present conditions are unusually favorable for securing great progress in astronomical science. It is hoped that a sum of at least $50,000 may be obtained for immediate expenditure, so that a beginning may be made at once, and astronomers may have an opportunity to show what results they might obtain with unrestricted means.

My one object is to secure a real advance in Astronomy. Any plan that will attain this, will have my hearty support, if desired. If this

advance is made, it is a matter of little importance whether the part taken by the Harvard Observatory, or by myself, is large or small.

Planet Notes for September and October.

Mercury will be at inferior conjunction Sept. 15 and so will not be visible until the last days of the month. On Oct. 1 the planet will be at greatest western elongation and may seen in the east in the morning for a few days. On the



THE CONSTELLATIONS, 9:00 P. M., OCTOBER 1, 1904.

last day of October it will be at superior conjunction. Mercury and Venus will be in conjunction in right ascension on the morning of Sept. 5. On the preceding and following evenings it may be possible for the reader to see both planets at the same time, although they will be pretty well hidden by the twilight. Look

almost directly west about a half hour after sunset. Mercury will be about six degrees south of Venus.

Venus is now evening star and is slowly coming out from behind the sun so as to be visible for a short time in the early evening. One should look almost due west, near the horizon, shortly after sunset, in order to see this planet. Daylight observations may be obtained with a telescope on any clear day. The markings on Venus, such as there are, have mostly been seen by day, when the planet was at a high altitude.

Mars is morning star, being near the meridian at 10 o'clock in the forenoon. The planet will not be in very favorable position for study during September, but in October work of value may perhaps be done upon its surface markings.

Jupiter is a fine object now in the morning sky, and will soon be visible all night. The giant planet will be at opposition Oct. 18 and, as it will then be eight degrees north of the equator, the conditions will be quite favorable for the study of the planet's surface.

Saturn is to be seen toward the south in the evening, and is during these two months in the most convenient position for amateur study for the year. The altitude of the planet is, however, so low at meridian passage, that only on the best nights will really satisfactory views be obtained. The planet is in the constellation Capricornus and is much brighter than any of the stars in the vicinity, so that anyone can easily recognize it.

Uranus will be at quadrature, 90° east from the Sun, on the morning of Sept. 19. The planet may be seen in the early evening, but is not in favorable position for study.

Neptune will be at quadrature, 90° west from the Sun, Oct. 1 and so may be found with a telescope in the morning in the constellation Gemini. Neptune will be at a stationary point of his apparent path on Oct. 11, so that it will be difficult to detect the planet by its motion during October.

The Moon.

(Central Standard Time at Northfield. Local Time 13m less.)

1904	Phases.	Rises h m	Sets h m
Sept. 2-3	Last Quarter	10 57 P. M.	1 52 P. M.
9	New Moon	5 21 A. M.	6 35 P. M.
16	First Quarter	1 30 P. M.	11 15 P. M.
24-25	Full Moon	6 16 P. M.	6 48 A. M.
Oct. 1-2	Last Quarter	10 30 P. M.	1 35 P. M.
8	New Moon	5 26 A. M.	5 39 P. M.
15	First Quarter	1 04 P. M.	10 54 P. M.
23-24	Full Moon	5 15 P. M.	6 40 A. M.
31-32	Last Quarter	11 27 P. M.	1 48 P. M.

Occultations Visible at Washington.

Date. 1904.		Star's Name.	Magni-tude.	IMMERSION. Washing-ton M.T. h	m	Angle fm N pt. °	EMERSION. Washing-ton M.T. h	m	Angle fm N pt. °	Dura-tion. h	m
Sept.	2	B. A. C. 1526	5.8	15	19	11	15	51	322	0	32
	3	130 Tauri	5.5	12	21	38	13	00	306	0	39
	29	85 Tauri	6.5	9	17	112	10	03	221	0	46
	29	B. A. C. 1406	7.5	10	23	19	10	56	312	0	33
	30	117 Tauri	6.3	10	31	112	11	20	228	0	49
Oct.	1	20 Geminorum	6.3	14	45	102	16	01	250	1	16
	1	21 Geminorum	6.5	14	45	101	16	01	251	1	16
	2	W.B. (2), vii, 685	5.6	16	00	53	17	04	314	1	04
	11	η Libræ	5.5	7	00	108	7	59	265	0	59
	12	24 Scorpii	5.2	6	58	84	8	03	281	1	05
	15	B. A. C. 6658	7.0	8	07	163	8	12	171	0	05

Occultations Visible at Washington.—(Continued.)

Date. 1904.		Star's Name.	IMMERSION. Magnitude.	Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Oct.	26	48 Tauri	6.4	7	29	109	8	17	222	0	48
	26	λ Tauri	3.9	9	29	119	10	17	208	0	48
	26	70 Tauri	6.3	13	07	119	14	12	213	1	05
	26	75 Tauri	6.3	15	02	78	16	27	264	1	25
	26	B. A. C. 1391	5.0	16	41	139	17	25	209	0	44
	26	B. A. C 1406	7.5	18	20	117	19	17	236	0	57
	26	α Tauri	1.0	19	28	79	20	27	277	0	59
	27	115 Tauri	5.4	18	23	19	18	44	344	0	21

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

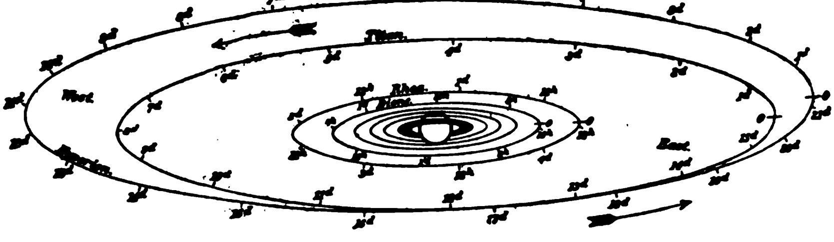
		h	m		
Sept.	1	8	59	P. M.	II Tr. In.
		9	16	"	II Sh. Eg.
		11	08	"	I Sh. In.
		11	23	"	II Tr. Eg.
	2	12	13	A. M.	I Tr. In.
		1	22	"	I Sh. Eg.
		2	24	"	I Tr. Eg.
		8	21	P. M.	I Ec. Dis.
		11	34	"	I Oc. Re.
	6	7	54	"	III Sh. In.
		10	05	"	III Sh. Eg.
	7	12	18	A. M.	III Tr. In.
		1	38	"	III Tr. Eg.
		3	00	"	II Ec. Dis.
	8	3	47	"	I Ec. Dis.
		9	22	P. M.	II Sh. In.
		11	22	"	II Tr. In.
		11	53	"	II Sh. Eg.
	9	12	02	A. M.	I Sh. In.
		1	45	"	II Tr. Eg.
		2	00	"	I Tr. In.
		3	15	"	I Sh. In.
		4	11	"	I Tr. Eg.
		10	15	P. M.	I Ec. Dis.
	10	1	21	A. M.	I Oc. Re.
		7	30	P. M.	I Sh. In.
		8	26	"	I Tr. In.
		8	30	"	II Oc. Re.
		9	44	"	I Sh. Eg.
		10	38	"	I Tr. Eg.
	11	7	48	"	I Oc. Re.
	13	11	55	"	III Sh. In.
	14	2	05	A. M.	III Sh. Eg.
		3	45	"	III Tr. In.
		5	05	"	III Tr. Eg.
	16	12	00	"	II Sh. In.
		1	42	"	II Tr. In.
		2	30	"	II Sh. Eg.
		2	56	"	I Sh. In.
		3	45	"	I Tr. In.
		4	06	"	II Tr. Eg.
	17	12	10	"	I Ec. Dis.
		3	07	"	I Oc. Re.
Sept.	17	9	24	P. M.	I Sh. In.
		10	12	"	I Tr. In.
		10	47	"	II Oc. Re.
		11	38	"	I Sh. Eg.
	18	12	23	A. M.	I Tr. Eg.
		9	34	P. M.	I Oc. Re.
	21	3	56	A. M.	III Sh. In.
	23	2	38	"	II Sh. In.
		4	01	"	II Tr. In.
		4	50	"	I Sh. In.
		5	08	"	II Sh. Eg.
	24	2	05	"	I Ec. Dis.
		4	52	"	I Oc. Re.
		7	51	P. M.	III Ec. Re.
		8	43	"	III Oc. Dis.
	24	9	27	P. M.	II Ec. Dis.
		10	03	"	III Oc. Re.
		[illegible]	[illegible]	"	I Sh. In.
		[illegible]	[illegible]	"	I Tr. In.
	25	1	03	A. M.	II Oc. Re.
		1	32	"	I Sh. Eg.
		2	07	"	I Tr. Eg.
		8	33	P. M.	I Ec. Dis.
		11	19	"	I Oc. Re.
	26	7	33	"	II Tr. Eg.
		8	00	"	I Sh. Eg.
		8	33	"	I Tr. Eg.
Oct.	1	10	00	"	III Ec. Dis.
		11	52	"	III Ec. Re.
	2	12	01	A. M.	III Oc. Dis.
		12	02	"	II Ec. Dis.
		1	13	"	I Sh. In.
		1	22	"	III Oc. Re.
		1	40	"	I Tr. In.
		3	17	"	II Oc. Re.
		3	26	"	I Sh. Eg.
		3	51	"	I Tr. Eg.
		10	28	P. M.	I Ec. Dis.
	3	1	03	A. M.	I Oc. Re.
		6	34	P. M.	II Sh. In.
		7	26	"	II Tr. In.
		7	41	"	I Sh. In.
		8	06	"	I Tr. In.

Phenomena of Jupiter's Satellites.—Continued.

	h	m				h	m		
Oct. 3	9	05	P. M.	II Sh. Eg.	Oct. 18	8	46	P. M.	I Oc. Dis.
	9	49	"	II Tr. Eg.		10	57	"	I Oc. Re.
	9	54	"	I Sh. Eg.	19	5	58	"	I Tr. In.
	10	17	"	I Tr. Eg.		5	58	"	I Sh. In.
4	7	29	"	I Oc. Re.		6	26	"	II Oc. Dis.
9	2	02	A. M.	III Ec. Dis.		8	03	"	III Sh. In.
	2	37	"	II Ec. Dis.		8	09	"	I Tr. Eg.
	3	07	"	I Sh. In.		8	12	"	I Sh. Eg.
	3	23	"	I Tr. In.		8	12	"	III Tr. In.
	4	40	"	III Oc. Re.		8	50	"	II Oc. Re.
10	12	28	"	I Ec. Dis.		9	42	"	III Tr. Eg.
	2	47	"	I Oc. Re.		10	06	"	III Sh. Eg.
	9	13	P. M.	II Sh. In.	20	5	24	"	I Ec. Re.
	9	36	"	I Sh In.	24	4	03	A. M.	I Oc. Dis.
	9	41	"	II Tr. In.	25	1	15	"	I Tr. In.
	9	49	"	I Tr. In.	25	1	24	A. M.	I Sh. In.
	11	43	"	II Sh. Eg.		2	11	"	II Tr. In.
	11	49	"	I Sh. Eg.		2	29	"	II Sh. In.
11	12	00	A. M.	I Tr. Eg.		3	27	"	I Tr. Eg.
	12	05	"	II Tr. Eg.		3	38	"	I Sh. Eg.
	6	52	P. M.	I Ec. Dis.		10	29	P. M.	I Oc. Dis.
	9	13	"	I Oc. Re.	26	12	51	A. M.	I Ec. Re.
12	6	06	"	III Sh. Eg.		7	41	P. M.	I Tr. In.
	6	17	"	I Sh. Eg.		7	53	"	I Sh. In.
	6	25	"	III Tr. Eg.		8	39	"	II Oc. Dis.
	6	26	"	I Tr. Eg.		9	52	"	I Tr. Eg.
	6	37	"	II Oc. Re.		10	06	"	I Sh. Eg.
17	2	18	A. M.	I Ec. Dis.		11	26	"	III Tr. In.
	4	31	"	I Oc. Re.		11	29	"	II Ec. Re.
	11	30	P. M.	I Sh. In.	27	12	05	A. M.	III Sh. In.
Oct. 17	11	32	P. M.	I Tr. In.		12	59	"	III Tr. Eg.
	11	51	"	II Sh. In.		2	06	"	III Sh. Eg.
	11	56	"	II Tr. In.		4	55	P. M.	I Oc. Dis.
18	1	43	A. M.	I Sh. Eg.		7	20	"	I Ec. Re.
	1	4[illegible]		I Tr. Eg.	28	5	43	"	II Tr. Eg.
	2	2[illegible]		II Tr. Eg.		6	18	"	II Sh. Eg.
	2	21		II Sh. Eg.					

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

The Satellites of Saturn.



Apparent orbits of the seven inner satellites of Saturn at opposition in 1904, as seen in an inverting telescope.

The Satellites of Saturn.—(Continued.)

Mimas. Period 0^d, 22.6^h.

		h					h					h		
Sept.	1	5.6	P. M.	E	Sept.	20	1.9	P. M.	E	Oct.	13	4.0	P. M.	W
	2	4.2	"	E		25	6.3	"	W		14	2.6	"	W
	3	2.8	"	E		26	4.9	"	W		19	7.0	"	E
	8	7.2	"	E		27	3.5	"	W		20	5.7	"	E
	9	5.6	"	W		28	2.1	"	W		21	4.3	"	E
	10	4.5	"	W	Oct.	3	6.5	"	E		22	2.9	"	E
	11	3.1	"	W		4	5.1	"	E		23	1.5	"	E
	16	7.4	"	E		5	3.8	"	E		28	6.0	"	W
	17	6.1	"	E		6	2.4	"	E		29	4.6	"	W
	18	5.6	"	E		11	6.8	"	W		30	3.2	"	W
	19	3.3	"	E		12	5.4	"	W		31	1.8	"	W

Enceladus. Period 1^d, 8.9^h.

Sept.	1	4.6	P. M.	E.	Sept.	20	8.9	P. M.	E.	Oct.	10	1.3	A. M.	E.
	3	1.5	A. M.	E.		22	5.8	A. M.	E.		11	10.2	"	E.
	4	10.3	"	E.		23	2.7	P. M.	E.		12	7.0	P. M.	E.
	5	7.2	P. M.	E.		24	11.5	"	E.		14	3.9	A. M.	E
	7	4.1	A. M.	E.		26	8.4	A. M.	E.		15	12.8	P. M.	E.
	8	1.0	P. M.	E.		27	5.3	P. M.	E.		16	9.7	"	E.
	9	9.9	"	E.		29	2.2	A. M.	E.		18	6.6	A. M.	E.
	11	6.7	A. M.	E.		30	11.1	"	E.		19	3.5	P. M.	E.
	12	3.6	P. M.	E.	Oct.	1	8.0	P. M.	E.		21	12.4	A. M.	E.
	14	12.5	A. M.	E.		3	4.9	A. M.	E.		22	9.3	"	E.
	15	9.4	"	E.		4	1.7	P. M.	E.		23	6.1	P. M.	E.
	16	6.3	P. M.	E.		5	10.6	"	E.		25	3.0	A. M.	E.
	18	3.1	A. M.	E.		7	7.5	A. M.	E.		26	11.9	"	E.
	19	12.0	. M.	E.		8	4.4	P. M.	E.		27	8.8	P. M.	E.

Tethys. Period 1^d, 21.3^h.

Sept.	3	3.8	A. M.	E.	Sept.	23	10.1	P. M.	E.	Oct.	14	4.4	P. M.	E.
	5	1.1	"	E.		25	7.4	"	E.		16	1.7	"	E.
	6	10.4	P. M.	E.		27	4.7	"	E.		18	11.0	A. M.	E.
	8	7.7	"	E.		29	2.0	"	E.		20	8.4	"	E.
	10	5.0	"	E.	Oct.	1	11.3	A. M.	E.		22	5.7	"	E
	12	2.3	"	E.		3	8.6	"	E.		24	3.0	"	E.
	14	11.6	A. M.	E.		5	5.9	"	E.		26	12.3	"	E.
	16	8.9	"	E.		7	3.2	"	E.		27	9.6	P. M.	E.
	18	6.2	"	E.		9	12.5	"	E.		29	6.9	"	E.
	20	3.5	"	E.		10	9.8	P. M.	E.		31	4.2	"	E.
	22	12.8	"	E.		12	7.1	"	E.					

Dione. Period 2^d, 17.7^h.

Sept.	3	1.0	A. M.	E.	Sept.	24	10.3	P. M.	E.	Oct.	14	2.1	A. M.	E.
	5	6.7	P. M.	E.		27	4.0	"	E.		16	7.8	P. M.	E.
	8	12.3	"	E.		30	9.7	A. M.	E.		19	1.5	"	E.
	11	6.0	A. M.	E.	Oct.	3	3.3	"	E.		22	7.1	A. M.	E.
	13	11.7	P. M.	E.		5	9.0	P. M.	E.		25	12.8	"	E.
	16	5.3	"	E.		8	2.7	"	E.		27	6.5	P. M.	E.
	19	11.0	A. M.	E.		11	8.4	A. M.	E.		30	12.2	"	E.
	22	4.7	"	E.										

Rhea. Period 4^d, 12.5^h.

Sept.	3	6.0	A. M.	E.	Sept.	25	7.7	P. M.	E.	Oct.	18	9.7	A. M.	E.
	7	6.3	P. M.	E.		30	8.1	A. M.	E.		22	10.1	P. M.	E.
	11	6.7	A. M.	E.	Oct.	4	8.5	P. M.	E.		27	10.6	A. M.	E.
	16	7.0	P. M.	E.		9	8.9	A. M.	E.		31	11.0	P. M.	E.
	21	7.3	A. M.	E.		13	9.3	P. M.	E.					

The Satellites of Saturn.—(Continued.)

Titan. Period 15^d, 23.3^h.

		h					h					h		
Sept.	4	11.1	A. M.	S.	Sept.	24	9.3	A. M.	E.	Oct.	14	10.9	A. M.	I.
	8	11.6	"	E.		28	12.4	P. M.	I.		18	9.3	"	W.
	12	2.7	P. M.	I.	Oct.	2	10.8	A. M.	W.		22	5.3	"	S.
	16	1.0	"	W.		6	6.8	"	S.		26	6.2	"	E.
	20	8.7	A. M.	S.		10	7.6	"	E.		30	9.6	"	S.

Hyperion. Period 21^d, 7.6^h.

Sept.	1.7	W.	Sept.	17.0	I.	Oct.	2.5	E.	Oct.	18.8	S.
	6.7	S.		22.8	W.		8.1	I.		23.7	E.
	11.4	E.		27.8	S.		14.0	W.		29.4	I.

Iapetus. Period 79^d, 22.1^h.

Aug.	28.1	W.	Sept.	16.7	S.	Oct.	5.7	E.	Oct.	25.5	I.

NOTE:—E denotes eastern elongation; I, inferior conjunction (south of planet); W, western elongation; S, superior conjunction (north of planet.)

COMET AND ASTEROID NOTES.

THE MOTION OF SHORT PERIOD COMETS.—In the last number of *Popular Astronomy,* page 413, the writer in speaking of Comet a 1904 said: "The fact that the inclination of the orbit is 125° would *a priori* suggest that the comet is not one of short period, for no known periodic comet has a retrograde motion around the Sun." A friend kindly calls attention to the fact that the remarkable comet known as Halley's comet, with a period of about 77 years, has a retrograde motion, the inclination of its orbit being 162°. This, of course, takes most of the force out of the above remark.

DEFINITIVE ORBIT OF COMET 1887 II.—In A. N. 3957 are given the results of a definitive determination by Mr. C. Stechert, of Hamburg, of the elements of the orbit of the comet 1887 II., which was discovered by Brooks at Phelps, N. Y., Jan. 22, 1887. The orbit appears to be elliptic with a period of about 1000 years. The best parbolic elements give residuals larger than are allowable.

ELEMENTS OF COMET 1887 II.

Osculation 1887 March 18.0.

$$\begin{aligned} T &= 1887 \text{ March } 17.4275940 \pm 0.0061984 \text{ Berlin M. T.} \\ \left.\begin{array}{r} \omega \\ \Omega \\ i \end{array}\right. & \left.\begin{array}{l} = 159^\circ\ 26'\ 15.00'' \pm 14.91'' \\ = 279\ \ 56\ \ 12.62 \pm 3.54 \\ = 104\ \ 16\ \ 10.47 \pm 3.18 \end{array}\right\} 1887.0 \\ \log q &= 0.2122261 \pm 0.0000095 \\ e &= 0.9836922 \pm 0.0002550 \\ \text{Period} &= 999.4 \text{ years} \end{aligned}$$

DEFINITIVE ORBIT OF COMET 1889 IV.—In A. N. 3957 are given the following definitive elements of the orbit of comet 1889 IV. computed by Dr. Guido Horn of Triest. This comet was discovered by Mr. J. Ewen Davidson of Mackay, Queensland, July 19,1889, and was followed at several observations up to Nov. 21 of that year. The excentricity in this case is very slight, the period determined being 9738.81 years.

ELEMENTS OF COMET 1889 IV.

$$T = 1889 \text{ July } 19.32298 \text{ Berlin M. T.}$$

$$\left.\begin{array}{l} \omega = 345^\circ\ 52'\ 42.83'' \\ \Omega = 286\ \ \ 9\ \ 18.31 \\ i = \ \ 65\ \ 59\ \ 11.17 \end{array}\right\} 1889.0 \qquad \begin{array}{l} \log q = 0.0169197 \\ \log e = 9.9990087 \\ \log a = 2.6590039 \end{array}$$

EPHEMERIS OF TEMPEL'S PERIODIC COMET 1873 II.—In A. N. 3962 Mr. J. Coniel gives an ephemeris computed from the following elements of M. Schulhof. These elements have been corrected for the perturbations by Jupiter and Saturn.

Epoch 1904 Oct. 30.0 Paris M. T.

$$\begin{array}{l} M = 357^\circ\ \ 51'\ \ 49.2'' \\ \left.\begin{array}{l} \omega = 185\ \ \ 44\ \ \ 38.6 \\ \Omega = 120\ \ \ 59\ \ \ 51.8 \\ i = \ \ 12\ \ \ 38\ \ \ 54.6 \end{array}\right\} 1904.0 \end{array} \qquad \begin{array}{l} \phi = 32^\circ\ \ 50'\ \ 03.7'' \\ \mu = 672.175'' \\ \log a = 0.4186829 \end{array}$$

Ephemeris of Comet Tempel₂ (1873 II) in 1904.

(For Paris Midnight.)

1904		α app. h	m	s	δ app. °	′	″	log Δ	Aber. m	s	$1:r^2\Delta^2$
Sept.	3	14	58	5.0	—9	2	55	0.23411	14	14	0.140
	4	15	0	18.8	9	20	19	23462		15	
	5		2	34.1	9	37	42	23512		16	
	6		4	50.8	9	55	4	23561		17	
	7		7	8.9	10	12	26	23610		18	0.142
	8		9	28.4	10	29	46	23658		19	
	9		11	49.5	10	47	5	23706		20	
	10		14	11.9	11	4	23	23753		21	
	11		16	35.8	11	21	38	23800		22	0.143
	12		19	1.1	11	38	51	23846		23	
	13		21	27.9	11	56	2	23891		24	
	14		23	56.1	12	13	10	23936		25	
	15		26	25.7	12	30	15	23981		26	0.145
	16		28	56.8	12	47	16	24025		27	
	17		31	29.4	13	4	14	24069		28	
	18		34	3.3	13	21	8	24113		28	
	19		36	38.7	13	37	57	24156		29	0.147
	20		39	15.0	13	54	42	24199		30	
	21		41	53.9	14	11	23	24242		31	
	22		44	33.6	14	27	58	24285		32	
	23		47	14.8	14	44	28	24327		33	0.149
	24		49	57.4	15	0	52	24370		34	
	25		52	41.5	15	17	11	24412		34	
	26		55	27.1	15	33	22	24455		35	
	27	15	58	14.1	15	49	27	24497		36	0.151
	28	16	1	2.5	16	5	26	24540		37	
	29		3	52.4	16	21	16	24583		38	
	30		6	43.8	16	36	59	24626		39	
Oct.	1		9	36.6	16	52	35	24669		40	0.152
	2		12	30.9	17	8	1	24712		41	
	3		15	26.6	17	23	19	24756		41	
	4		18	23.8	17	38	28	24800		42	
	5		21	22.4	17	53	28	24844		43	0.154
	6		24	22.5	18	8	18	24888		44	
	7		27	24.0	17	22	57	24933		45	
	8		30	26.9	18	37	26	24979		46	
	9		33	31.3	18	51	45	25025		47	0.155
	10		36	37.1	19	5	51	25071		48	
	11		39	44.3	19	19	47	25117		49	
	12		42	52.9	19	33	30	25165		50	
	13		46	2.8	19	47	1	25212		51	0.155
	14		49	14.1	20	0	19	25261		52	
	15		52	26.6	20	13	24	25310		53	
	16		55	40.9	20	26	16	25360		54	
	17	16	58	56.2	20	38	53	25410		55	0.156
	18	17	2	12.9	20	51	16	25461		56	
	19		5	30.8	21	3	25	25513		57	
	20		8	50.0	21	15	19	25566		58	
	21		12	10.5	21	26	57	25619	14	59	0.156
	22		15	32.2	21	38	20	25674	15	0	
	23		18	55.1	21	49	26	25729		1	
	24		22	19.2	22	0	16	25786		3	
	25	17	25	44.5	—22	10	50	0.25843		4	

The comet will be very faint at this apparition but Mr. Coniel thinks that the ephemeris is very exact, so that the comet may possibly be found.

EPHEMERIS OF ENCKE'S COMET.—In AN 3962 Messrs. Kaminsky and Ocoulitsch give an approximate ephemeris of Encke's Comet, using Thonberg's elements corrected for the perturbations by Jupiter. The elements brought up to this year are

Epoch and osculation 1904 Nov. 9.0 Berlin M. T.

$$\left.\begin{aligned} M &= 341^\circ\ 3'\ 39.64'' \\ \pi &= 159\ \ 2\ \ 39.41 \\ \Omega &= 334\ \ 27\ \ 8.24 \\ i &= 12\ \ 35\ \ 37.32 \end{aligned}\right\}1904.0 \qquad \begin{aligned} \phi &= 57^\circ\ 54'\ 20.51''-2.394''\tau \\ \mu &= 1075.66611''+0.069299''\tau \\ \log a &= 0.3455527 \end{aligned}$$

EPHEMERIS OF ENCKE'S COMET.

(For Berlin Noon.)

1904		α app. h	m	s	δ app. °	′	log r	log Δ	Aber. h	m
Sept.	3	1	51	50	—24	14.5	0.3289	0.1422	11	32
	4		51	28	24	23.4	3268	1358		22
	5		51	4	24	32.3	3247	1294		12
	6		50	36	24	41.2	3226	1229	11	2
	7		50	6	24	50.0	3205	1163	10	52
	8		49	33	24	58.9	3183	1097		42
	9		48	57	25	7.6	3161	1031		32
	10		48	18	25	16.3	3139	0964		22
	11		47	35	25	25.1	3117	0896		12
	12		46	38	25	33.8	3094	0828	10	3
	13		45	58	25	42.5	3072	0759	9	53
	14		45	5	25	51.1	3049	0690		44
	15		44	8	25	59.5	3026	0621		35
	16		43	6	26	8.0	3002	0551		26
	17		42	0	26	16.3	2979	0480		17
	18		40	51	26	24.6	2955	0409	9	8
	19		39	38	26	32.8	2931	0338	8	59
	20		38	20	26	40.9	2906	0266		50
	21		36	57	26	48.8	2882	0194		41
	22		35	30	26	56.6	2857	0121		33
	23		33	58	27	4.3	2832	0.0048		24
	24		32	21	27	11.8	2806	9.9974		16
	25		30	39	27	19.1	2781	9900	8	7
	26		28	51	27	26.2	2755	9826	7	59
	27		26	59	27	33.1	2729	9752		51
	28		25	1	27	39.8	2702	9677		43
	29		22	58	27	46.3	2675	9602		35
	30		20	49	27	52.4	2648	9527		27
Oct.	1		18	33	27	58.2	2621	9452		19
	2		16	12	28	3.5	2593	9377		12
	3		13	44	28	8.5	2565	9302	7	4
	4		11	11	28	13.2	2536	9226	6	57
	5		8	31	28	17.4	2508	9150		50
	6		5	44	28	21.2	2479	9076		43
	7	1	2	51	28	24.4	2450	9002		36
	8	0	59	52	28	27.0	2420	8927		29
	9		56	47	28	29.2	2390	8853		22
	10		53	35	28	30.7	2359	8779		16
	11		50	16	28	31.6	2328	8705		10
	12		46	51	28	31.7	2297	8632	6	4
	13		43	20	28	31.1	2265	8550	5	58
	14		39	42	28	29.6	2233	8489		52
	15		35	57	28	27.3	2201	8418		46
	16	0	32	7	—28	24.2	0.2168	9.8350	5	41

EPHEMERIS OF COMET A 1904 (1904 I).—The following ephemeris is by A. A. Nijland from elements in AN 3952. The comet is growing quite faint and will be observed with difficulty with small telescopes.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1904		α h	m	s	δ °	′	log Δ	Brightness
Sept.	4	12	19	25	—43	41.4	0.5996	0.22
	6		19	57	43	32.7		
	8		20	31	43	24.6	0.6022	0.22
	10		21	6	43	17.1		
	12		21	43	43	10.2	0.6043	0.21
	14		22	21	43	3.9		
	16		22	59	42	58.3	0.6061	0.21
	18		23	38	42	53.3		
	20		24	18	42	48.9	0.6074	0.20
	22		24	58	42	45.2		
	24		25	39	42	42.1	0.6083	0.20
	26		26	20	42	39.6		
	28		27	2	42	37.8	0.6088	0.19
	30		27	43	42	36.7		
Oct.	2		28	25	42	36.2	0.6090	0.19
	4		29	7	42	36.5		
	6		29	48	42	37.4	0.6088	0.19
	8		30	29	42	39.1		
	10		31	9	42	41.4	0.6081	0.19
	12		31	49	42	44.6		
	14		32	28	42	48.4	0.6071	0.18
	16		33	6	42	53.0		
	18		33	43	42	59.3	0.6058	0.18
	20		34	18	43	4.4		
	22		34	53	43	11.3	0.6042	0.18
	24		35	26	43	19.0		
	26		35	58	43	27.6	0.6022	0.18
	28		36	28	43	37.0		
	30	12	36	56	—43	47.3	0.5999	0.18

NEW ASTEROIDS.—The following have been added to the list of new planets since our last note:

	Discovered by	at		Local M. T. h m	R. A. h m	Decl. ° ′	Mag.
1904 OC	Dugan	Heidelberg	1904 May 7	9 52.9	15 06.4	—10 21	12.2
1904 OD	Dugan	Heidelberg	11	10 19.4	14 55.3	—18 36	12.2
1904 OE	Wolf	Heidelberg	1904 May 13	12 05	15 50.7	— 3 51	13.4
1904 OF	Peters	Washington	12	14 04.8	15 55.7	—19 08	11.7
1904 OG	Charlois	Nice	July 7	10 30	19 01.2	—17 52	11.7
	Götz	Heidelberg	14	12 45.4	18 55.8	—18 33	12.0
1903 OH	Peters	Washington	1903 Apr. 28	12 22	14 29.3	— 7 08	12.0
1903 OJ	Peters	Washington	June 29	12 00	18 28.2	—14 38	12.0

NUMBERING OF ASTEROIDS.—The following recently discovered minor planets have received permanent numbers:

No.	Provisional Designation	Discovered		Discoverer.
(513)	1903 LY	1903 Aug.	24	Wolf
(514)	1903 MB		24	Wolf
(515)	1903 ME	Sept.	20	Wolf
(516)	1903 MG		20	Dugan
(517)	1903 MH		22	Dugan
(518)	1903 MO	Oct.	20	Dugan
(519)	1903 MP		20	Dugan
(520)	1903 MV		27	Wolf and Götz
(521)	1904 NB	1904 Jan	10	Dugan

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

U Cephei.

	d	h
Sept.	1	2
	3	14
	6	2
	8	13
	11	1
	13	13
	16	1
	18	13
	21	1
	23	12
	26	0
	28	12
	30	24
Oct.	3	12
	5	24
	8	11
	10	23
	13	11
	15	23
	18	11
	20	22
	23	10
	25	22
	28	10
	30	22

Z Persei

	d	h
Sept.	4	0
	7	1
	10	3
	13	4
	16	5
	19	7
	22	8
	25	10
	28	11
Oct.	1	12
	4	14
	7	15
	10	16
	13	18
	16	19
	19	20
	22	22
	25	23
	29	0

Algol.

	d	h
Sept.	3	13
	6	10
	9	7
	12	3
	15	0
	17	21
	20	18
	23	15
	26	12
	29	8
Oct.	2	5
Oct.	5	2
	7	23
	10	20
	13	16
	16	13
	19	10
	22	7
	25	4
	28	1
	30	21

λ Tauri.

	d	h
Sept.	3	16
	7	15
	11	14
	15	12
	19	11
	23	10
	27	9
Oct.	1	8
	5	7
	9	6
	13	5
	17	3
	21	2
	25	1
	29	0

R Canis Maj.

	d	h
Sept.	1	18
	2	22
	4	1
	5	4
	6	7
	7	11
	8	14
	9	17
	10	20
	11	24
	13	3
	14	6
	15	9
	16	13
	17	16
	18	19
	19	22
	21	2
	22	5
	23	8
	24	12
	25	15
	26	18
	27	21
	29	1
	30	4
Oct.	1	7
	2	10
	3	14
	4	17
	5	20
Oct.	6	23
	8	3
	9	6
	10	9
	11	13
	12	16
	13	19
	14	22
	16	2
	17	5
	18	8
	19	11
	20	15
	21	18
	22	21
	24	0
	25	4
	26	7
	27	10
	28	13
	29	17
	30	20
	31	23

V Puppis.

	d	h
Sept.	1	21
	3	7
	4	18
	6	5
	7	16
	9	3
	10	14
	12	1
	13	12
	14	23
	16	10
	17	21
	19	7
	20	18
	22	5
	23	16
	25	3
	26	14
	28	1
	29	12
	30	23
Oct.	2	10
	3	21
	5	7
	6	18
	8	5
	9	16
	11	3
	12	14
	14	1
	15	12
	16	23
	18	10
	19	21
Oct.	21	7
	22	18
	24	5
	25	16
	27	3
	28	14
	30	1
	31	12

S Cancri

	d	h
Sept.	2	2
	11	13
	21	1
	30	12
Oct.	10	0
	19	12
	28	23

S Antliæ.
Period
$7^h\ 46^m.8$

	d	h
Oct.	1	20
	2	19
	3	18
	4	18
	5	17
	6	16
	7	16
	8	15
	9	14
	10	14
	11	13
	12	13
	13	12
	14	11
	15	11
	16	10
	17	9
	18	9
	19	8
	20	7
	21	7
	22	6
	23	5
	24	5
	25	4
	26	3
	27	3
	28	2
	29	1
	30	1
	31	0

S Velorum

	d	h
Sept.	6	1
	11	23
	17	21
	23	20
	29	18
Oct.	5	17
Oct.	11	15
	17	13
	23	12
	29	10

W Ursæ Maj.
Period $4^h\ 0^m.1$

Sep.	1-16	9
Sep.	16-30	10
Oct.	1-31	10

RR Velorum.

	d	h
Sept.	1	18
	3	14
	5	11
	7	7
	9	4
	11	0
	12	21
	14	17
	16	14
	18	10
	20	7
	22	3
	23	23
	25	20
	27	17
	29	13
Oct.	1	10
	3	6
	5	3
	6	23
	8	20
	10	16
	12	13
	14	9
	16	6
	18	2
	19	23
	21	19
	23	16
	25	12
	27	9
	29	5
	31	2

Z Draconis.

	d	h
Sept.	1	19
	3	4
	4	12
	5	21
	7	6
	8	14
	9	23
	11	7
	12	16
	14	0
	15	9
	16	18
	18	2

Minima of the Variable Stars of the Algol Type.—Continued.

Z Draconis

	d	h
Sept.	19	11
	20	19
	22	4
	23	13
	24	21
	26	6
	27	14
	28	23
	30	7
Oct.	1	16
	3	1
	4	9
	5	18
	7	2
	8	11
	9	20
	11	4
	12	13
	13	21
	15	6
	16	14
	17	23
	19	8
	20	16
	22	1
	23	9
	24	18
	26	2
	27	11
	28	20
	30	4
	31	13

δ Libræ.

	d	h
Sept.	2	18
	5	2
	7	10
	9	18
	12	2
	14	10
	16	17
	19	1
	21	9
	23	17
	26	1
	28	9
	30	17
Oct.	3	0
	5	8
	7	16
	10	0
	12	8
	14	16
	16	24
	19	7
	21	15
	23	23
	26	7
	28	15
	30	23

U Coronæ.

	d	h
Sept.	3	6
	6	17
	10	3
	13	14
	17	1
	20	12
	23	23
	27	10
	30	21
Oct.	4	7
	7	18
	11	5
	14	16
	18	3
	21	14
	25	1
	28	11
	31	22

R Aræ.

	d	h
Sept.	4	23
	9	10
	13	20
	18	6
	22	16
	27	2
Oct.	1	13
	5	23
	10	9
	14	19
	19	5
	23	16
	28	2

U Ophiuchi.

	d	h
Sept.	1	2
	1	22
	2	18
	3	15
	4	11
	5	7
	6	3
	6	23
	7	19
	8	15
	9	11
	10	8
	11	4
	12	0
	12	20
	13	16
	14	12
	15	8
	16	5
	17	1
	17	21
	18	17
	19	13
	20	9
	21	5

U Ophiuchi.

	d	h
Sept.	22	1
	22	22
	23	18
	24	14
	25	10
	26	6
	27	2
	27	22
	28	18
	29	15
	30	11
Oct.	1	7
	2	3
	2	23
	3	19
	4	15
	5	11
	6	8
	7	4
	8	0
	8	20
	9	16
	10	12
	11	8
	12	4
	13	1
	13	21
	14	17
	15	13
	16	9
	17	5
	18	1
	18	22
	19	18
	20	14
	21	10
	22	6
	23	2
	23	22
	24	18
	25	15
	26	11
	27	7
	28	3
	28	23
	29	19
	30	15
	31	12

Z Herculis

	d	h
Sept.	1	15
	3	18
	5	15
	9	15
	15	18
	17	15
	23	17
	25	14

Z Herculis.

	d	h
Oct.	1	17
	3	14
	9	17
	11	14
	17	16
	19	13
	25	16
	27	13

RS Sagittarii

	d	h
Sept.	2	4
	7	0
	11	20
	16	16
	21	11
	26	7
Oct.	1	13
	5	22
	10	19
	15	15
	20	11
	25	7
	30	3

RX Herculis.

	d	h
Sept.	1	17
	3	11
	5	6
	7	1
	8	19
	10	14
	12	9
	14	3
	15	22
	17	17
	19	11
	21	6
	23	1
	24	19
	26	14
	28	9
	30	3
Oct.	1	1
	2	20
	4	14
	6	9
	8	4
	9	22
	11	17
	13	12
	15	6
	17	1
	18	20
	20	14
	22	9
	24	4
	25	22
	27	17
	29	12
	31	6

RV Lyræ

	d	h
Sept.	3	1
	10	6
	17	11
	24	16
	31	20
Oct.	8	1
	15	6
	22	11
	29	15

U Sagittæ.

	d	h
Sept.	4	3
	10	22
	17	16
	24	10
Oct.	1	4
	7	23
	14	17
	21	11
	28	6

SY Cygni.

	d	h
Sept.	4	20
	16	21
	28	21
Oct.	10	21
	22	22

SW Cygni.

	d	h
Sept.	1	23
	11	2
	20	6
	29	9
Oct.	8	13
	17	16
	26	20

UW Cygni.

	d	h
Sept.	1	21
	8	18
	15	16
	22	14
	29	11
Oct.	6	9
	13	7
	20	4
	27	2

W. Delphini

	d	h
Sept.	3	4
	12	19
	22	10
Oct.	2	0
	11	15
	21	6
	30	20

VV Cygni.

	d	h
Sept.	1	13
	4	12
	7	11
	10	10

Minima of the Variable Stars of the Algol Type.—Continued.

VV Cygni.	d	h
Sept.	13	9
	16	8
	19	6
	22	5
	25	4
	28	2
Oct.	1	2
	4	1
	7	0
	9	23

VV Cygni.	d	h
Oct.	12	22
	15	21
	18	19
	21	18
	24	17
	27	16
	30	15
VW Cygni.		
Sept.	4	2

VW Cygni.	d	h
Sept.	20	22
Oct.	7	19
	24	16
Y Cygni.		
Sept.	2	23
	4	14
	8	23
	10	14
	14	23

Y Cygni.	d	h
Sept.	16	14
	20	22
	22	13
	26	22
	28	13
Oct.	2	22
	4	13
	8	22
	10	13
	14	22

Y Cygni.	d	h
Oct.	16	13
	20	22
	20	22
	22	13
	26	22
	28	13
UZ Cygni.		
Sept.	21	10
Oct.	22	17

Variable Stars of Short Period not of the Algol Type.

Star		Minimum. d	h		Maximum. d	h
V Carinæ	Sept.	1	4	Sept.	3	8
κ Pavonis		1	7		5	2
T Velorum		1	8		2	7
S Muscæ		1	9		4	20
Y Sagittarii		1	19		3	14
S Sagittæ		2	3		5	13
R Crucis		2	20		4	5
V Centauri		3	4		4	15
U Sagittarii		3	7		6	6
T Vulpeculæ		3	12		4	21
β Lyræ		3	15		6	22
η Aquilæ		3	19		6	4
U Vulpeculæ		3	20		5	23
S Crucis		3	21		5	9
ζ Geminorum		3	21		8	21
X Sagittarii		3	22		6	19
RV Scorpii		4	3		5	13
SU Cygni		4	4		5	12
δ Cephei		4	6		5	15
U Aquilæ		4	9		6	13
S Trianguli Austr.		4	13		6	15
T Velorum		4	14		5	23
TX Cygni		5	2		10	5
W Sagittarii		5	9		8	9
T Crucis		5	12		7	13
V Velorum		5	17		6	16
T Monocerotis		5	22		13	20
Y Sagittarii		7	13		9	8
S Normæ		7	18		12	4
V Carinae		7	20		10	00
T Vulpeculæ		7	23		9	8
SU Cygni		8	0		9	8
W Geminorum		8	7		10	22
S Crucis		8	14		10	2
R Crucis		8	16		10	1
V Centauri		8	16		10	2
U Sagittarii		9	1		12	0
β Lyræ		9	2		12	4
T Velorum		9	6		10	15
δ Cephei		9	15		11	0
η Aquilæ		10	0		12	4
V Velorum		10	2		11	1
RV Scorpii		10	4		11	14
κ Pavonis	Sept.	10	9	Sept.	14	4
S Sagittæ		10	12		13	22
Y Ophiuchi		10	18		16	23
S Trian. Austr.		10	21		12	23
X Sagittarii		10	22		13	19
S Muscæ		11	1		14	12
U Aquilæ		11	9		13	13
SU Cygni		11	20		13	4
U Vulpeculæ		11	20		13	23
T Crucis		12	5		14	6
T Vulpeculæ		12	9		13	18
W Sagittarii		12	23		15	23
S Crucis		13	6		14	18
Y Sagittarii		13	8		15	3
T Velorum		13	21		15	6
ζ Geminorum		14	1		19	1
V Centauri		14	4		15	15
V Velorum		14	11		15	10
R Crucis		14	12		15	21
X Cygni		14	13		20	18
V Carinæ		14	14		16	18
δ Cephei		14	23		16	8
β Lyræ		15	13		18	20
SU Cygni		15	16		17	0
U Sagittarii		15	19		18	18
W Geminorum		16	01		18	16
RV Scorpii		16	6		17	16
T Vulpeculæ		16	19		18	4
η Aquilæ		17	4		19	13
S Triang. Austr.		17	5		19	7
W Virginis		17	11		25	16
S Normæ		17	12		21	22
S Crucis		17	23		19	11
X Sagittarii		17	23		20	20
U Aquilæ		18	11		20	15
T Velorum		18	13		19	22
V Velorum		18	19		19	18
S Sagittæ		18	21		22	7
T Crucis		18	23		21	0
Y Sagittarii		19	2		20	25
κ Pavonis		19	11		23	6
SU Cygni		19	13		20	21
V Centauri		19	16		21	3

Variable Stars of Short Period not of the Algol Type.—(Continued.)

	Minimum.			Maximum.		
		d	h		d	h
U Vulpeculæ	Sep.	19	19	Sept.	21	22
TX Cygni		19	20		24	23
R Crucis		20	8		21	17
δ Cephei		20	8		21	17
W Sagittarii		20	13		23	13
S Muscæ		20	16		24	3
T Vulpeculæ		21	5		22	14
V Carinæ		21	6		23	10
β Lyræ		22	0		25	2
RV Scorpii		22	7		23	17
U Sagittarii		22	13		25	12
S Crucis		22	15		24	3
V Velorum		23	4		24	3
T Velorum		23	4		24	13
SU Cygni		23	9		24	17
S Triang. Austr.		23	13		25	15
W Geminorum		23	19		26	10
ζ Geminorum		24	5		29	5
η Aquilæ		24	8		26	17
Y Sagittarii		24	21		26	16
X Sagittarii		24	23		27	20
V Centauri		25	4		26	15
U Aquilæ		25	11		27	15
T Crucis		25	16		27	17
T Vulpeculæ		25	16		27	1
δ Cephei		25	17		27	2
R Crucis		26	4		27	13
SU Cygni		27	6		28	14
S Sagittæ		27	6		30	16
S Normæ		27	6		31	16
S Crucis		27	8		28	20
V Velorum		27	13		28	12
T Velorum		27	19		29	4
U Vulpeculæ		27	19		29	22
Y Ophiuchi		27	21	Oct.	4	2
V Carinæ		27	23	Sept.	30	23
W Sagittarii		28	4		31	4
RV Scorpii		28	9		29	19
β Lyræ		28	11	Oct.	1	18
κ Pavonis		28	13		2	8
U Sagittarii		29	7		2	6
S Triang. Austr.		29	21		1	23
T Vulpeculæ		30	2		1	11
S Muscæ		30	8		3	19
Y Sagittarii		30	15		2	10
V Centauri		30	16		2	3
X Cygni		30	22		7	3
SU Cygni	Oct.	1	2		2	10
δ Cephei		1	2		2	11
η Aquilæ		1	12		3	21
W Geminorum		1	12		4	3
V Velorum		1	22		2	21
X Sagittarii		1	23		4	20
R Crucis		2	0		3	9
S Crucis		2	0		3	12

	Minimum.			Maximum.		
		d	h		d	h
T Velorum	Oct.	2	10	Oct.	3	19
T Crucis		2	10		4	11
U Aquilæ		2	12		4	16
T Monocerotis		2	22		10	29
ζ Geminorum		4	8		9	8
RV Scorpii		4	10		5	20
T Vulpeculæ		4	13		5	22
TX Cygni		4	13		9	16
V Carinæ		4	17		6	21
SU Cygni		4	22		6	6
β Lyræ		4	22		8	0
S Sagittæ		5	15		9	1
U Vulpeculæ		5	18		7	21
W Sagittarii		5	18		8	18
U Sagittarii		6	1		9	0
V Centauri		6	3		7	14
S Triang. Austr.		6	4		8	6
V Velorum		6	7		7	6
δ Cephei		6	10		7	19
Y Sagittarii		6	11		8	6
S Crucis		6	17		8	5
S Normæ		7	0		11	10
T Velorum		7	2		8	11
κ Pavonis		7	16		11	11
R Crucis		7	19		9	4
η Aquilæ		8	17		11	2
SU Cygni		8	18		10	2
T Vulpeculæ		8	23		10	8
X Sagittarii		9	0		11	21
T Crucis		9	2		11	3
W Geminorum		9	6		11	21
U Aquilæ		9	12		11	16
S Muscæ		10	0		13	11
RV Scorpii		10	12		11	22
V Velorum		10	16		11	15
S Crucis		11	9		12	21
V Carinæ		11	9		13	13
β Lyræ		11	9		14	16
V Centauri		11	15		13	2
T Velorum		11	17		13	2
δ Cephei		11	19		13	4
Y Sagittarii		12	5		14	0
S Triang. Austr.		12	12		14	14
SU Cygni		12	15		13	23
U Sagittarii		12	19		15	18
W Sagittarii		13	8		16	8
T Vulpeculæ		13	10		14	19
R Crucis		13	15		15	0
U Vulpeculæ		13	18		15	21
S Sagittæ		14	1		17	11
ζ Geminorum		14	12		19	12
Y Ophiuchi		15	0		21	5
V Velorum		15	1		16	0
T Crucis		15	21		17	22
η Aquilæ		15	21		18	6

Approximate Magnitudes of Variable Stars Aug. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
T Androm.	0 17.2	+ 26 26	*f*	R Camel.	14 25.1	+ 84 17	9
T Cassiop.	0 17.8	+ 55 14	*f*	R Bootis	14 32.8	+ 27 10	12.5*d*
R Androm.	0 18.8	+ 38 1	11*d*	S Librae	15 15.6	— 20 2	10*d*
S Ceti	0 19.0	— 9 53	*u*	S Serpentis	15 17.0	+ 14 40	9*i*
S Cassiop.	1 12.3	+ 72 5	14	S Coronae	15 17.3	+ 31 44	11*d*
R Piscium	1 25.5	+ 2 22	*u*	S Urs. Min.	15 33.4	+ 78 58	10
R Trianguli	1 31.0	+ 33 50	*u*	R Coronae	15 44.4	+ 28 28	6.0
U Persei	1 52.9	+ 54 20	8*i*	V "	15 45.9	+ 39 52	9*d*
R Arietis	2 10.4	+ 24 36	8d	R Serpentis	15 46.1	+ 15 26	6.0*d*
o Ceti	2 14.3	— 3 26	*s*	R Herculis	16 1.7	+ 18 38	*f*
S Persei	2 15.7	+ 58 8	*u*	*R Scorpii	16 11.7	— 22 42	*f*
R Ceti	2 20.9	— 0 38	*s*	S "	16 11.7	— 22 39	15*d*
U "	2 28.9	— 13 35	*s*	U Herculis	16 21.4	+ 19 7	12*d*
R Persei	3 23.7	+ 35 20	*u*	W Herculis	16 31.7	+ 37 32	14*d*
R Tauri	4 22.8	+ 9 56	*s*	R Draconis	16 32.4	+ 66 58	*u*
S "	4 23.7	+ 9 44	*s*	S Herculis	16 47.4	+ 15 7	8*i*
R Aurigæ	5 9.2	+ 53 28	11*d*	R Ophiuchi	17 2.0	— 15 58	8*i*
U Orionis	5 49.9	+ 20 10	10*d*	T Herculis	18 5.3	+ 31 0	12*d*
R Lyncis	6 53.0	+ 55 28	*f*	R Scuti	18 42.2	— 5 49	5*i*
R Gemin.	7 1.3	+ 22 52	*s*	R Aquilae	19 1.6	+ 8 5	10*d*
S Canis Min.	7 27.3	+ 8 32	*s*	R Sagittarii	19 10.8	— 19 29	9*i*
R Cancri	8 11.0	+ 12 2	*s*	S "	19 13.6	— 19 12	*u*
V "	8 16.0	+ 17 36	*s*	R Cygni	19 34.1	+ 49 58	14*d*
S Hydrae	8 48.4	+ 3 27	*s*	RT "	19 40.8	+ 48 32	12*d*
T "	8 50.8	— 8 46	*s*	X "	19 46.7	+ 32 40	10*i*
R Leo. Min.	9 39.6	+ 34 58	*s*	S Cygni	20 3.4	+ 57 42	11*d*
R Leonis	9 42.2	+ 11 54	*s*	RS "	20 9.8	+ 38 28	8*i*
R Urs. Maj.	10 37.6	+ 69 18	7	R Delphini	20 10.1	+ 8 47	*u*
R Comae	11 59.1	+ 19 20	8*i*	U Cygni	20 16.5	+ 47 35	8.0*d*
T Virginis	12 9.5	— 5 29	*s*	V "	20 38.1	+ 47 47	12*d*
R Corvi	12 14.4	— 18 42	*s*	T Aquarii	20 44.7	— 5 31	8*i*
Y Virginis	12 28.7	— 3 52	15*f*	R Vulpec.	20 59.9	+ 23 26	13*d*
T Urs. Maj.	12 31.8	+ 60 2	9*d*	T Cephei	21 8.2	+ 68 5	9.0*d*
R Virginis	12 33.4	+ 7 32	8*d*	S "	21 36.5	+ 78 10	10*d*
S Urs. Maj.	12 39.6	+ 61 38	11*d*	S Lacertae	22 24.6	+ 39 48	8
U Virginis	12 46.0	+ 6 6	10*d*	R "	22 38.8	+ 41 51	9
V "	13 22.6	— 2 39	11*i*	S Aquarii	22 51.8	— 20 53	*u*
R Hydrae	13 24.2	— 22 46	8*d*	R Pegasi	23 1.6	+ 10 0	8
S Virginis	13 27.8	— 6 41	9*i*	S "	23 15.5	+ 8 22	*u*
R Can. Ven.	13 44.6	+ 40 2	7*i*	R Aquarii	23 38.6	— 15 50	*u*
S Bootis	14 19.5	+ 54 16	9*i*	R Cassiop.	23 53.3	+ 50 50	11*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the McCormick, Eadie and Harvard Observatories.

*Invisible in McCormick 26-inch telescope.

Maxima of Y Lyræ.

Period 12ʰ 03.9ᵐ. The minimum occurs 1ʰ 40ᵐ before the maximum.

	d	h		d	h		d	h		d	h
Sept.	1-5	10	Sept.	22-28	13	Oct.	1-6	14	Oct.	22-29	17
	6-13	11		29-30	14		7-14	15		29-31	18
	14-21	12					15-21	16			

Variable Star Notes.

A recent maximum of S S Cygni was observed as follows:

1904, June 3, 10:30 P. M. Less bright than 6 classed as 8.3 magnitude, brighter than a or c classed as 9.2.
1904, June 4, 9:40 P. M. Nearer to a and c; and probably of 9th magnitude.
1904, June 6, 9:45 P. M. Equal to a.
1904, June 8, 10:05 P. M. Less than a, brighter than d of 10.5 magnitude.
1904, June 9, 10:10 P. M. Slightly brighter than d.
1904, June 10, 10:15 P. M. Equal to nand d.
1904, June 11, 9:40 P. M. Dimmer than n or d.
1904, June 12, 9:50 P. M. Just discernible; not far from 12th magnitude.

S W CYGNI.

This variable of the Algol type has a period of about 4 days and 13 hours. In these odd hours it declines and regains light varying nearly 3 magnitudes.

1904, June 2, 9:40 P. M. Equal to f classed as 9.2 magnitude.
1904, June 3, 10:35 P. M. Brighter than f less than a of 8.6 magnitude.
1904, June 4, 10:05 P. M. Nearly equal to a.
1904, June 6, 9:25 P. M. Nearly equal to a.
1904, June 8, 10:10 P. M. Nearly equal to a.
1904, June 9, 10:05 P. M. Nearly equal to a.
1904, June 11, 10:10 P. M. Dimmer than l classed as 9.8. Brighter than o of 10.9 magnitude.
1904, June 20, 9:25 P. M. Equal to f.

V ORIONIS.

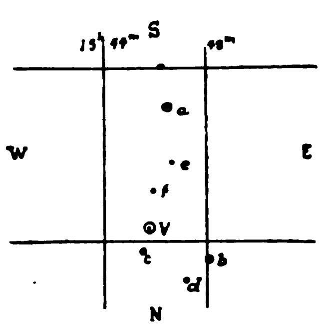
The phases of this variable were rather elusive in the last two seasons, but the following intermediate observations were obtained under favorable conditions.

1904, Jan. 4 and 6, Invisible.
1904, Jan. 11, of 12 magnitude.
1904, Jan. 14, 11.8 magnitude. Night very clear.
1904, Jan. 17, 19, 20, 24, the same
1904, Jan. 29, Invisible in moonlight.
1904, Feb. 7, Of about 10th magnitude.
1904, Feb. 17, The same. The comparison stars used were those forming a line with it a few minutes of an arc in length.

V CORONAE.

1904, March 21, Reddish in hue. Equal to c.
1904, April 10, Brighter than c; equal to b.
1904, April 17, Brighter than c; not fully equal to b.
1904, May 2, Equal to c.
1904, May 14, The same.
1904, May 18, It seems equal to b.
1904, June 4, Dimmer than c; much brighter than f.

As these estimates were made on rather clear nights when moonlight was



VICINITY OF V CORONÆ.

absent or faint, a maximum seems to have occurred some weeks later than the predicted date, March the 8th. In the accompanying diagram, the letters are affixed in the order of magnitude.

R HYDRAE.

It is two centuries since the variability of this star was first proved, and though generally invisible without magnifying power, it attains to 4 or 5 magnitude for several weeks during its long period of 425 days.

1904, March 21, About 5.5 magnitude being less than Gamma and brighter than Psi in the tail of the Hydra.
1904, April 10, Decreased, but still brighter than Psi.
1904, May 1, Less than Psi about 6.3.
1904, May 15, Probably 6.5. Not visible without an opera glass.

V HYDRAE.

During February and March several observations were taken of this red star which was of 7 magnitude and visible in an opera glass. It varies from 6.7 to 0.5 during its long irregular period. ROSE O'HALLORAN.

San Francisco, July 3, 1904.

THE DISCOVERY OF NEW VARIABLE STARS.—Since the issue of the June and July number of *Popular Astronomy* the number of variables, for which provisional notation has been assigned by the Astronomische Gesellschaft Committee, has risen to 141 for the year 1904, the increase resulting largely from the publication of Harvard Circulars Nos. 76-81, which contain the results of the examination of photographic plates at Harvard during this year and last. And now comes to hand Circular No. 82 with the positions of 152 new variables found in the Large Magellanic Cloud.

Owing to lack of space we are obliged to omit these from this number of *Popular Astronomy,* but hope to bring our notes up to date in the October issue.

NEW VARIABLES 108, 109 AND 110, 1904.—These are announced by Prof. W. Ceraski, of Moscow, in A. N. 3953. Their positions are:

	α1855.0			δ1855.0		α1900.0			δ1900.0		Mag.
	h	m	s	°	′	h	m	s	°	′	
108 . 1904 Cass.	23	30	29	+61	37.7	23	32	23	+61	52.6	9-11
109 . 1904 Lyræ	19	05	14	+43	2.5	19	06	39	+43	29	10-13
110 . 1904 Lacertæ	22	42	44	+55	33.4	22	44	33	+55	47.6	8.5-9.5

The first of these stars is B. D.+61°.2487 and its period is unknown. The second is an anonymous star and its period is probably several weeks or months. The third is B. D. +55°.2815 and is also found in the Helsingfors A. G. Catalogue No. 13453. Some of the photographs seem to indicate that the period is short,—2 or 3 days from maximum to minimum.

NEW VARIABLES 111 AND 112, 1904 AQUILAE.—Prof. M. Wolf in A. N. 3954 says that the space in the vicinity of the "triple hole" in the constellation Aquila is full of stars whose light seems to vary. This variation is so small that as yet it is not well determined, but he gives two stars whose variation is beyond doubt. Their positions for 1900.0 are:

	α			δ			Magnitude	
	h	m	s	°	′	″	July 19, 1901	Sept. 24, 1903
111 . 1904 Aquilæ	19	33	40.66	+10	22	02.1	13.0	<15
112 . 1904 Aquilæ	19	34	12.46	+10	16	35.7	12.7	11.2

These variables in the vicinity of one of the curious dark spaces in the Milky Way are of special interest, since they may possibly furnish some data for the study of the question whether the dark spaces are produced simply by the absence of stars or by the intervention of dark matter between us and the stars.

NEW VARIABLE 113, 1904 URSAE MINORIS.—This is announced by Prof. W. Ceraski in A. N. 3956. It is nearly 4′ southeast of the star B. D. +67°.830, and varies between 8.5 and 12 magnitude. Its position is:

α1855.0	δ1855.0	α1900.0	δ1900.0
h m	° ′	h m	° ′
14 14.0	+67 23	14 14.9	+67 10

S ANTLIAE.—In A. N. 3955 Mr. M. Luizet of Lyons, France, gives a new determination of the period and light curve of this star. His elements are obtained from observations by Sawyer, Yendell, Paul, Sperra and Luizet, covering the period from 1890 to 1903.

$$\text{Minimum (Paris M. T.)} = 1888 \text{ April } 13\ 12^h\ 44.9^m + 0^d\ 7^h\ 46^m\ 48.233^s\ E$$
$$= \text{JD. } 2410741.5312 \pm 0.0087 + (0.32416936 \pm 0.00000094)\ E$$

The curve shows that the variation is rapid about the minimum but that it is slow, scarcely perceptible, for about three hours around the maximum. It agrees very closely with that of Mr. Sperra given in A. J. 413.

Y SAGITTARII.—In A. N. 3955 Mr. M. Luizet also gives a new determination of the light curve of this variable star. This gives practically no correction to the period as given in Chandler's Third Catalogue, except that the interval from maximum to minimum is made 1.97 days instead of 1.8 days, agreeing with that given by Sawyer in A. J. 328. The form of the light curve differs but little from that of Sawyer.

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h		d	h		d	h		d	h
Sept.	1	5	Sept.	16	22	Oct.	2	1	Oct.	17	18
	3	11		19	4		4	7		20	0
	5	17		21	10		6	13		22	6
	7	23		23	15		8	19		24	12
	10	5		25	21		11	1		26	18
	12	10		28	3		13	7		29	0
	14	16		30	9		15	13		31	5

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
Sept.	1	17	Sept.	18	2	Oct.	2	9	Oct.	18	18
	3	18		20	3		4	10		20	19
	5	19		22	4		6	11		22	20
	7	20		24	5		8	13		24	21
	9	21		26	6		10	14		26	22
	11	23		28	7		12	15		28	23
	14	0		30	8		14	16		31	0
	16	1					16	17			

GENERAL NOTES.

Continued absence from home for two months has made the appearance of this number of our publication a few days later than was anticipated.

A considerable amount of important variable star matter that should appear in this issue, for want of space, must be deferred until our next number.

We are fortunate in being able to present to our readers, this time, an excellent notice of the life and astronomical work of the late Dr. Isaac Roberts. The photograph and sketch were furnished at our request, by one who knew him well and intimately for years.

The brilliant meteorite that probably fell within a few miles of Northfield, Minn., during the month of July last has not yet certainly been identified. Several people have picked up stones resembling meteorites, but all, so far as we know, lack the certain evidence of identification in regard to time and place to make any claim reasonably sure. At the time of fall the detonations were so marked and so well heard by many persons that there seems to be little doubt but that its fall must have been near the place mentioned.

THE PERSEIDS AT WILMINGTON, N. C.—The display became marked on the night of the 10th about 9 o'clock P. M. and continued until observation ceased at about twelve midnight, though it may have continued longer. Between those hours meteors came at the rate of twenty-five to thirty per hour. On the night of the 11th the same occurred again, beginning at the same time and with almost the same frequency, twenty-five to thirty, on an average per hour. Very few were seen on the 12th and the 13th, and on the 14th I do not recall one. I have never seen as fine a display of the August Meteors before.—E. S. Martin, Wilmington, N. C., Aug. 15, 1904.

It was announced that the Carnegie Institution has made a grant of fifteen hundred dollars in continuation of last year's grant aiding the New Reduction of Piazzi's 160,000 Star Observations. This work, under the direction of Dr. Herman S. Davis, Gaithersburg, Md., is now well advanced. Previous assistance has been rendered by the late Miss Catherine W. Bruce and by the National Academy of Science which continues its aid. A re-observation of all the southern stars of Piazzi's catalogue, by Prof. Tucker, has recently been issued as Vol. VI of "Lick Observatory Publications." A similar work for all the northern stars, by Prof. Porter, will be an early publication of the Cincinnati Observatory. Other co-operators, in this country and in Europe, are expected to complete the entire catalogue in five years or less. It has now been in progress nearly eight years.—SCIENCE, April 29, 1904.

NEW FAINT SATELLITE BELONGING TO SATURN.—In 1899 Professor William H. Pickering, from an examination of photographs taken for the purpose with the 24-inch Bruce Telescope, discovered a new and faint satellite of Saturn, having a period of about a year and a half. See H. C. O. Circular No. 43. A further discussion of a large number of photographs has served to deter-

mine the elements of its orbit. Eleven photographs taken by Mr. Frost at the Arequipa Station, under the direction of Professor Bailey, enable us to follow the satellite from April 16 to June 9, 1904, and to correct its ephemeris. A full discussion by Professor Pickering will appear in a few weeks in a forthcoming volume of the Annals. Meanwhile, to enable astronomers elsewhere to observe it at once, its position angle and distance from Saturn may be stated to be on July 14, $77^{\circ}.4$ and 17 .8, on July 24, $79^{\circ}.8$ and $14'.3$, and on August 3, 1904, $84^{\circ}.0$ and $10'.5$, respectively.—Edward C. Pickering, Harvard College Observatory, Bulletin No. 155, July 19, 1904.

August Meteors Observed at Barre, N. Y.—A beautiful display of the August meteors, those known as the Perseids, was seen at this place on the eve of Aug. 11. In less than three hours' watching 154 meteors were counted, of which 116 were Perseids, and easily traceable to the radiant in Perseus. Their flight was slow, leaving heavy luminous trains behind, which in some cases lasted over three minutes. One very large and beautiful meteor left its train in Aquila some ten degrees in length, resembling a fixed golden bar hanging along the milky way for nearly four minutes, when it gradually dissolved and faded away. They were often seen to travel in pairs, with parallel paths, both being about the same magnitude. The radiant seems to have shifted to the westward, being not far from the Star "Iota" Persei, which is some ten degrees from the place given by Mr. Denning. Many other meteors, either sporadic or belonging to other groups were seen, but were feeble when compared with the Perseids.—Weston Wetherbee.

La Fête du Soleil.—A rather novel festival was held at Paris on the night of June 21 last, at the time of the summer solstice. It was called "The Festival of the Sun" and was held in the Eiffel Tower, which Mr. Eiffel placed at the disposal of the Astronomical Society of France for that night. Mr. Eiffel also gave a banquet to the members of the Society, after which a conference was held in which Professor Camille Flammarion made the principal address. The exact moment when the sun was at the solstice was announced by the discharge of a cannon, and this moment was chosen for the beginning of the conference. There were stereopticon views of the surface of the sun and musical and poetical numbers to help pass away the hours of the night, for one of the principal events of the festival was the view of the sunrise from the upper part of the Tower. The records of the tower show that over 500 guests were present at the banquet, that 243 ascended to the third platform of the tower and that 118 of them remained to see the sun rise.

Estimates of Brightness on Photographic Plates.—In A. N. 3949 Professor Max Wolf gives an interesting note on this subject. He finds that the order in brightness of a series of stars may differ in photographs taken at the same moment with lenses of different type. The apparent brightness of a star as judged from the photographic image depends upon the color of the star, the distribution of the light in its spectrum, the character and sensitiveness of the emulsion from which the film on the plate was formed, the length of the exposure, the method of development of the plate, the quality of the observer's eye, the manner of illuminating the plate for examination, etc., as well as upon

the real brightness of the star and the size and type of lens. Different combinations of all these different conditions may produce decided variations in the order of apparent brightness of a series of stars differing only slightly in real brightness. It seems to the writer of this note that small or even considerable apparent variations in the brightness of very faint stars are to be accepted with great hesitation, until they are verified by visual observations or are proved to have a regular period.

A LUNAR RAINBOW.—In POPULAR ASTRONOMY, Vol. VII, page 500, I called attention to a lunar rainbow seen at the Strait of Gibraltar on the evening of October 17, 1899. It was remarkable because of its great brightness and the clearness of the prismatic colors, and also because of the very manifest secondary bow. The frequency of lunar rainbows, of any intensity, is not great. (See POPULAR ASTRONOMY VIII, 54.)

Tonight (June 29, 1904) Mrs. Davis called my attention to another similar display. The complete arc was very plain from horizon to horizon, almost a semi-circle as the moon was only a few degrees high and the view unobstructed by mountains. The spectrum colors were not clearly defined, however, as in the former case: neither was the secondary bow to be seen, though I did suspect that I could glimpse the extremities of it by "averted vision." The primary bow was visible from 9:30 until nearly 10:00 p. m. standard time,—and was witnessed by the three persons now at this observatory.

INTERNATIONAL LATITUDE OBSERVATORY, HERMAN S. DAVIS.
GAITHERSBURG, MARYLAND.

THE ORBIT OF THE COMPANION OF SIRIUS.—In A. N. 3955 Dr. O. Lohse gives a new determination of the orbit of the companion to Sirius. He obtains the following elements:

$T = 1894.337$	$\Omega = 44.12°$
Period $= 50.381$ years	$i = 39.91$
$n = -7.14559°$	$\omega = 212.20$
$e = 0.598$	$a = 7.427''$

The observations with few exceptions are well represented.

The following ephemeris shows that the star will not be difficult to observe during the next decade.

EPHEMERIS OF SIRIUS' COMPANION.

Beginning of year	Position Angle °	Distance "	Beginning of year	Position Angle °	Distance "
1904	116.2	6.6	1909	95.1	8.7
1905	110.9	7.0	1910	92.0	9.0
1906	106.3	7.5	1911	89.1	9.4
1907	102.2	7.9	1912	86.4	9.7
1908	98.4	8.3	1913	83.9	10.1

MR. HINKS' REDUCTION OF PHOTOGRAPHS OF EROS.—In the *Monthly Notices* of the British Royal Astronomical Society for June, 1904, Mr. A. R. Hinks of the Cambridge Observatory, England, gives a discussion of the results of an elaborate reduction of the measures of 295 photographs of Eros, contributed by nine observatories. Forty-six photographs were rejected for various reasons, leaving 249 which were used in the final solution for the Solar Parallax. These photographs were all taken during the week Nov. 7-15, 1900, and the

measures were taken with reference to a special list of comparison stars selected by Mr. Hinks. He took the original measures, furnished by the nine observatories, and reduced them all according to one plan, so as to avoid any systematic errors of reduction entering into the deduced parallax. From the very thorough way in which Mr. Hinks has treated this problem we may have a great deal of confidence in the result he has obtained, although it depends upon a very small part of the data which should soon be available from the great number of Eros photographs which were taken in 1900 and 1901. The result is not to be regarded as definitive, but it is gratifying to note its close agreement with the result obtained by Dr. Gill from Heliometer measures of Victoria and Sappho in 1889. The value of the solar parallax which Mr. Hinks obtains is

$$\pi = 8.7966'' \pm 0.0047''$$

The accuracy of the measures of the plates which were employed is shown in the following table:

Observatory	No. of Plates	Adopted Weight	Average Residual in Star Places In X	Average Residual in Star Places In Y	Average Residual in Equations In X	Average Residual in Equations In Y
			"	"	"	"
Algiers	31	⅔	0.16	0.12	0.109	0.111.
Cambridge	39	1			.152	.129
Camoridge	11	⅔	0. 1	0.10	.132	.080
Cambridge	54	1			.105	.087
Lick	28	1	.10	.12	.101	.093
Northfield	21	¼	.18	.17	.111	.134
Oxford	30	⅔	.17	.17	.134	.105
Paris	21	1	.10	.11	.093	.099
Tacubaya	14	1/10	0.28	0.19	0.128	0.103

The measures from two observatories had to be omitted because of abnormal discordances. On the Paris plates the mean of three exposures was taken. On all the others each exposure was treated as a separate plate although several were upon the same plate.

The last paragraphs of Mr. Hinks' paper contain so many valuable suggestions that we give them in full:

"Inasmuch as the principal object of this work was to discover what would happen when one tried to combine the results of a number of observatories into one solution, we may sum up very briefly the outcome of the experiment as follows:

"The labour of forming the system of standard stars of considerable relative accuracy found its reward in the facility with which systematic errors were discovered. So soon as confidence in the accuracy of the system was established, the appearance of large residuals became the signal for a search after systematic error; and the search was not often in vain. If the error was found to increase rapidly from the centre, and the outer stars had to be rejected, there were generally enough standard stars near the centre to give a good solution. If the error proved to be guiding error, and the brighter stars were rejected, there remained enough stars of magnitude nearly equal to that of the planet. In fact the treatment of diverse material demands that the standard stars should be fainter, and more evenly distributed close to the planet's path than are the *repère* stars. And one can hardly overestimate the advantage that arose from the perfect simplicity of the linear reductions in rectangular co-ordinates.

"The finding of occasional guiding error is satisfactory, if only because it was quite certain *a priori* that it must from time to time occur. The absence of

any evidence of hour-angle error is the more satisfactory, because that error might reasonably be feared. The discovery that the field of the Crossley reflector becomes useless immediately outside the limit of sensibly perfect definition leaves it still unexplained why the error should take the particular form that it does; while the quite unexpected large errors in the Algiers plates, taken with a refrac'or of standard pattern, cannot fail to inspire many stimulating doubts as to the absolute value of results obtained with one instrument alone. At the same time the elimination of the larger part of the systematic errors, which seems to have been achieved, assures us at once of the practicability of making a general solution, and of the difficulty of treating the results of any one observatory apart from the others.

"The force of the latter conclusion is increased if one may accept the reality of the oscillation in the position of the planet of short period and semi-amplitude about $0''.03$. This oscillation might well be entangled with the parallax displacements in a quite considerable series of observations made at a single observatory; it is completely separated from the parallax when a general solution is made; and the search for it throughout the period of observation of the planet will make a beautiful test of the real delicacy of our results.

"It seems that we may draw, from the experience gained in the work of the present paper, the conclusion that future work would be greatly facilitated by the adoption of a close system of standard stars. The formation of the system that I have used made a considerable part of the whole labour. But in future the task will be very much lightened, because it will be possible to make the star system depend upon the very extensive series of star places derived from the work of the four French observatories. If we have a standard system whose relative places are known with a probable error of a few hundredths of a second we can get as much accuracy as an individual plate is capable of giving by measuring the planet and eight or ten of these stars well distributed around it. With such a standard system we can discover systematic errors, provided that the residuals in the reduction of the stars are open to inspection; but if any such error is found, it is of the greatest advantage to have at hand the original measured co-ordinates. It is doubtful whether those observatories whose aim is to contribute their results in the form most convenient for a general reduction of all the material could do better than publish simply the original measures. It will probably pay better to give the man who undertakes a general solution the means to carry out reduction *ab initio,* rather than to do any part of it before publication, for the discovery of some systematic error when the observations are combined with others will often necessitate a new reduction.

"Finally, if we are able to admit that these conclusions are sound, we are led to the proposition that any observatory with photographs of *Eros* still unmeasured can make its contribution to the definitive determination of the solar parallax of greatest effect by agreeing to select its stars from a close standard system, and doing as speedily as possible the absolute minimum of work. It is the hope of the writer that he may be allowed to submit, in the near future, a selection of standard stars for consideration."

Expedition for Solar Research.—With the aid of a grant of $10,000 from the Carnegie Institution, for use during the current year, the Yerkes Observatory of the University of Chicago has sent an expedition to Mount Wilson (5886

feet) near Pasadena, California, for the purpose of making special investigations of the Sun. The principal instrument to be erected on the mountain is the Snow horizontal telescope, recently constructed in the instrument and optical shops of the Yerkes Observatory as the result of a gift from Miss Helen Snow of Chicago. This telescope is a coelostat reflector, the coelostat mirror having a diameter of 30 inches. A second plane mirror, 24 inches in diameter, reflects the beam from the coelostat north to either one of two concave mirrors, each of 24 inches aperture. One of these concave mirrors, of about 60 feet focal length, is to be used in conjunction with a solar spectrograph of 5 inches aperture and 13 feet focal length; a spectroheliograph of 7 inches aperture, resembling the Rumford spectroheliograph of the Yerkes Observatory; and a stellar spectrograph provided with a large concave grating, and mounted in a constant temperature laboratory. It is hoped that it will be possible with this stellar spectrograph to photograph the spectra of a few of the brightest stars. For fainter stars, the spectrograph is to be provided with several prisms, for use singly or in combination.

The second concave mirror of the coelostat reflector is designed to give a large focal image of the Sun, especially adapted for investigations with a powerful spectroheliograph and for spectroscopic studies of Sun-spots and other solar phenomena. The focal length of this mirror is about 145 feet, so that it will give a solar image about 16 inches in diameter. The spectroheliograph for use with this large solar image, is to be of 7 inches aperture and 30 feet focal length. For the present, until a suitable grating can be obtained, the dispersive train of this instrument will consist of three prisms of 45° refracting angle, used in conjunction with a plane mirror, so as to give a total deviation of 180°. The motion of the solar image, of which a zone about 4 inches wide can be photographed with the spectroheliograph, will be produced by rotating the concave mirror about a vertical axis by means of a driving clock. A second driving clock, controlled electrically so as to be synchronous with the first driving clock, will cause the photographic plate to move behind the second slit. Three slits will be provided at this point, so as to permit photographs to be taken simultaneously through as many different lines of the spectra. It is hoped that this spectroheliograph will prove to be well suited for use with some of the narrower dark lines of the solar spectrum.

The work of the expedition is under the immediate direction of Professor George E. Hale, Director of Yerkes Observatory. During his absence Professor E. B. Frost will be in immediate charge of the Yerkes Observatory, with the title of acting director. Professor Frost will also be the managing editor of the Astrophysical Journal. Mr. Ferdinand Ellerman and Mr. Walter S. Adams will be associated with Professor Hale in the work on Mt. Wilson.

Professor G. W. Ritchey, Superintendent of Instrument Construction at the Yerkes Observatory, will be in charge of an instrument shop which is being fitted up for the expedition at Pasadena.

An Elogy on Sir Isaac Newton.

(Translated from the Latin of Dr. Halley.)

Behold the regions of the heav'ns survey'd
And this fair system in the balance weigh'd!
Behold the law, which (when in ruin hurl'd

God out of chaos call'd the beauteous world)
Th' Almighty fix'd, when all things good he saw;
Behold the chaste, inviolable law;
Before us new scenes unfolded lie
And heav'n appears expanded to the eye:
Th' illumin'd mind now sees distinctly clear
What pow'r impels each planetary sphere.
Thron'd in the center glows the king of day,
And rules all nature with unbounded sway;
Thro' the vast void his subject planets run,
Whirl'd in their orbits by the regal sun.
What course the dire tremendous comets steer
We know, nor wonder at their prone career;
Why silver Phœbe, meek-ey'd queen of night,
Now slackens, now precipitates her flight;
Why, scan'd by no astronomers of yore,
She yielded not to calculation's pow'r;
Why the Node's motions retrograde we call,
And why the Apsides progressional.
Hence too we learn, with what proportion'd force
The moon impels, erroneous in her course,
The refluent main: as waves on waves succeed,
On the bleak beach they toss the sea-green weed,
Now bare the dangers of th' engulfing sand,
Now swelling high roll foaming on the strand.
What puzzling school-men sought so long in vain,
See cloud-dispelling Mathesis explain!
O highly blest, to whom kind fate has given
Minds to expatiate in the fields of heaven,
All doubts are clear'd, all errors done away,
And truth breaks on them in a blaze of day.
Awake, ye sons of men, arise! exclude
Far from your breasts all low solicitude;
Learn hence the mind's ætherial pow'rs to trace,
Exhalted high above the brutal race.
Ev'n those fam'd chiefs who human life refin'd
By wholesome laws, the fathers of mankind;
Or they who first societies immur'd
In cities, and from violence secur'd;
They who with Ceres' gifts the nations blest,
Or from the grape delicious nectar prest;
They who first taught th' hieroglyphic stile
On smooth *papyrus, native plant of Nile,
(For literary elements renown'd)
And made the eye an arbiter of sound;
All these, tho' men of deathless fame, we find

*An Egyptian plant, growing in the marshy places near the banks of the Nile, on the leaves of which the ancients used to write.

Have less advanc'd the good of human-kind:
Their schemes were founded on a narrower plan,
Replete with few emoluments to man.
But now, admitted guests in heav'n, we rove
Free and familiar in the realms above;
The wonders hidden deep in earth below,
And nature's laws, before conceal'd, we know.
Lend me your aid, ye bright superior pow'rs,
That live embosom'd in Elysian bow'rs,
Lend your sweet voice to warble Newton's praise,
Who searcht out truth thro' all her mystic maze,
Newton, by every fav'ring muse inspir'd,
With all Apollo's radiations fir'd;
The nice barrier 'twixt human and divine. —EUGENIO.

The foregoing English verses together with the title thereof and note, are after an autographic copy made under the direction of C. K. Bolton, Esq., Librarian of the Boston Athenaeum, Boston, Mass., where may be found a copy of the volume in which they were originally printed; i. e., the 'General Magazine of Arts and Sciences,' by Benjamin Martin, for the year 1755, Vol. I., page 4 of the Miscellaneous Correspondence for January, 1755. The original Latin hexameters, composed by Dr. Halley and by him prefixed to the first edition of Newton's *Principia* (together with the unauthorized changes made therein, in connection with the second and third editions of the same work) were incorporated in the appendix to Brewster's Life of Newton, (editions of 1855 and 1860.)—Eugene Fairfield McPike.

ASTRONOMICAL OBSERVATIONS AT MIDVALE, MONT.—June 29, 1904, Dr. H. C. Wilson and Professor W. W. Payne started from Northfield, Minn., on a trip to the Rocky Mountains for the purpose of doing some astronomical work that might be favorably done at a higher altitude than that of Goodsell Observatory. We took with us 2150 lbs. of astronomical instruments and a complete camp outfit in order to stay at least through two dark moons for time enough to photograph some regions in the vicinity of the Milky Way whose nebulosity has been suspected from the time of the elder Herschel, but which have not yet been sufficiently studied to determine their character by the effective means of celestial photography.

By the aid of interested and generous friends and by the courtesy of the officials of the Chicago Great Western and the Great Northern Companies, this expedition was made possible, comfortably convenient and scientifically successful in some important particulars which will be given more explicitly in a later number of this publication when the results of the photographic work are in shape for publication.

After reaching the Rocky Mountains, by a most delightful run over the main lines of the railways just mentioned, whose fine equipment and lavish accommodations make western travel a perfect luxury, we stopped at Midvale, Mont., situated on the eastern border of the mountains 1133 miles north and west of St. Paul, Minnesota. After somewhat careful search in the vicinity of this place, for a suitable location to do out-of-door photographic work, one was found which seemed to be satisfactory for the work contemplated. The place

chosen for mounting our 8¼-inch photographic telescope and the 6-inch Brashear photographic comera and other astronomical apparatus was 1235 feet north and west of the station, Midvale, Mont., on the Great Northern Railway. Its altitude is about 4800 feet above sea-level and well protected from prevailing winds on the west, northwest and southwest by the main range of the Rocky Mountains quite near by. The immediate place where the instruments were mounted was surrounded on the remaining sides, by a semi-circular hill of moderate height which afforded some protection to the instruments, while at work, from the shake of occasional surface winds. In these particulars we were fortunate in our location, and in the conveniences of the place for camp living, during our stay continuously for forty-eight days.

During the dark of the Moon following the first of July, the photographic work went on unexpectedly well, at night between the hours of 10 o'clock p. m. and 3 o'clock a. m., which was about the period of time that could be used in view of late and early twilight. The very faint nebulous regions under photographic exposure required the very best conditions for delicately sensitive plates to work in that could possibly be secured. Just what was done and the success attending our efforts, as we have before said, will be told later.

The unexpected drawbacks that hindered our work were comparatively few, but some of them were rather serious. One was the change in temperature from day to night. During the day it was common for the thermometer to register from 80° to 90°, while at night the record was liable to be as low as 40° and sometimes several degrees lower. This great change during the 24 hours and the low temperature reached during the night brought heavy dews which wet the objectives so much as to interfere with long exposures when they were desired. The use of paper dew-caps helped the situation somewhat, but did not remove the difficulty entirely. With dew-caps properly constructed better results would certainly have been realized. A more serious hindrance to our work was the smoke that came from the forest fires in the mountains west of us. The whole region in our vicinity was so densely smoke-laden that much of the time we could not see the outlines of the mountains less than five miles away. During the dark of the Moon in August we tried to do a little photographing when the smoke seemed least in the way, but the results were unsatisfactory. On this account we lost one-half of our time for the photographic work planned, and of course were sorely disappointed, although we know such a trouble could neither be helped nor anticipated. The forest fires in the mountains were this year on account of the drouth more severe than they have been for many years in the past. Some very interesting things were noticed while the photographic work was going on to which a brief reference only can now be made. One was the very blue sky that always met the observer's eye in a clear and moonless night. This was a surprise, for we expected to see at such an altitude a blacker sky than we had been accustomed to see at lower positions in other places. Another thing was the excessive brilliancy of the stars on good and steady nights for observation. This effect would be expected on the background of a black sky, but the blue sky instead of the black behind such stellar splendor was for us a very rare sight.

Still another thing was the curious fact that when clouds came over the mountains from the west or around them from other directions, they would often vanish completely before they reached the zenith of our observing position. Such changes were very welcome when long exposures were desired.

Another very favorable circumstance which we often noticed was concerning the behavior of winds and air currents. Many times light or strong winds would come up about noon, or a little earlier, and continue during the rest of the day, but almost invariably they would fall and entirely cease at sunset and remain so until the coming of early morning hours or considerably later.

Other interesting features of this expedition will be given later.

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WM. W. PAYNE,
Northfield, Minn., U. S. A.

PLATE XVIII.

N.

THE AMERICA NEBULA NEAR α CYGNI.

Photographed with a 2½-inch Darlot Lens at Midvale, Montana. Exposure 3 hours.

Popular Astronomy.

Vol. XII No. 8. OCTOBER, 1904. Whole No. 118.

CELESTIAL PHOTOGRAPHY AT A HIGH ALTITUDE.

H. C. WILSON.

During the past summer it was the writer's pleasure, with Professor Payne, to spend the months of July and August in the foot-hills of the Rocky Mountains in Montana, experimenting in celestial photography. One of the main objects of our expedition was to determine whether or not there might be great advantage for photographic purposes, especially the photography of the faint nebulous regions of the sky, in the high altitude which we could reach there over our moderate altitude on the Minnesota prairie. We wished to determine this by taking photographs of the same objects, with the same apparatus, using the same quality of plates, developed by the same person in as nearly the same manner as possible in both locations. The last condition could not be quite exactly fulfilled, because we could not transport our dark room, and the development at the temporary station had to be done without some of the conveniences which are to be found in a permanent dark room.

The location chosen was at Midvale, Montana, a station on the Great Northern Railroad just at the east edge of the first spur of the Rockies. Through the courtesy of the officials of the Chicago Great Western and the Great Northern Companies our party of four and baggage were transported free of charge to Midvale. Other interested friends contributed toward our expenses, but the fund was not large enough to permit us to go far from the railroad and to establish our station on the summit of one of the mountains as we might have desired. Considering the necessity of being near water and fuel, and of protection from the wind, as well as the convenience of being near a railroad station, we selected a small plateau 1,235 feet distant and a little north of west from the railroad station, surrounded by low hills and trees a short distance away, with the range of high mount-

ain peaks a few miles to the west shielding us from the prevailing west winds.

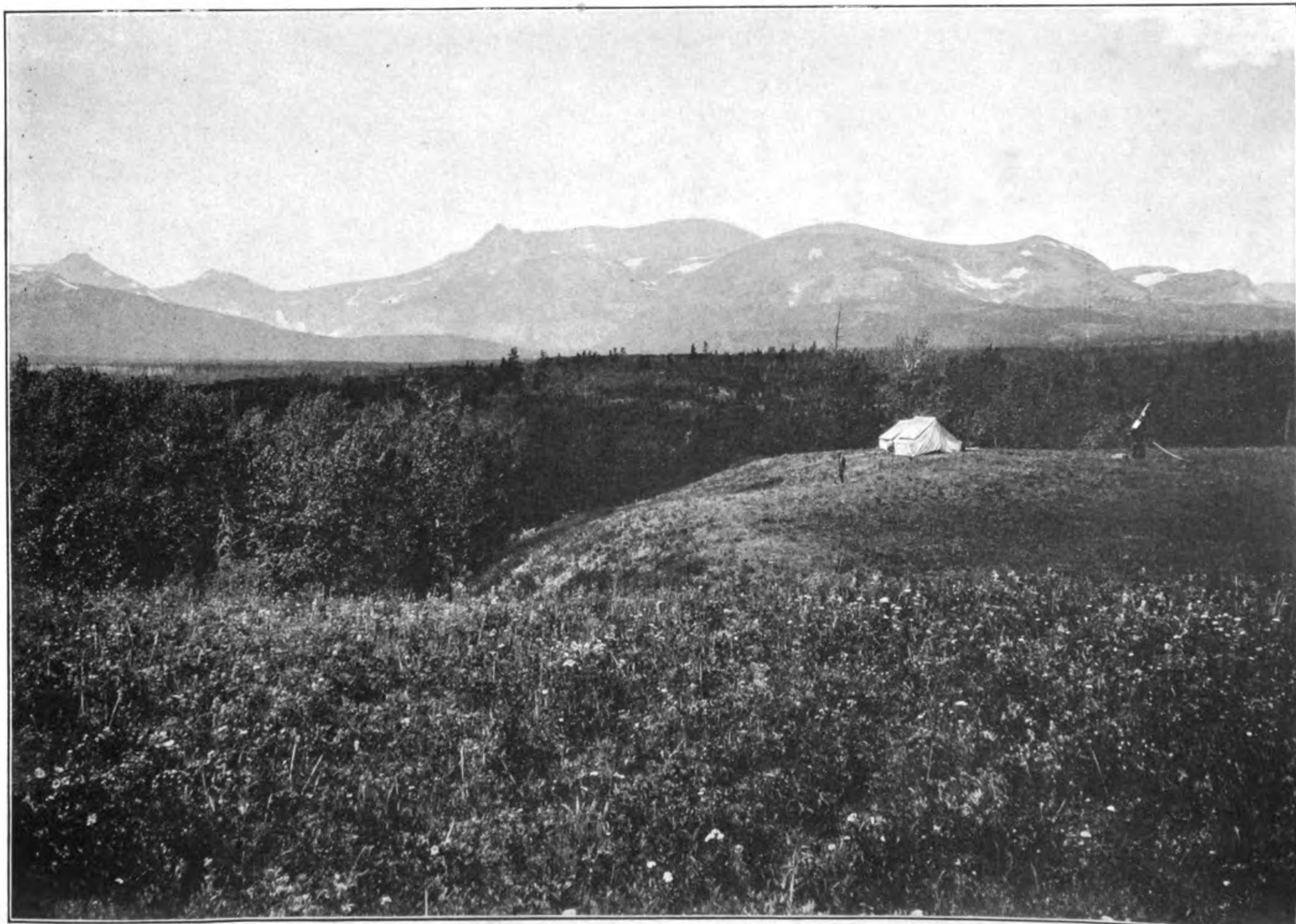
A part of this plateau and of the mountain range is shown in the engraving Plate XIX. Our sleeping tents are seen to the right of the center and the telescope near the right edge of the picture. The height of this plateau above sea level, as determined by a series of levels from a mark established by the U. S. Geological Survey, is 4,790 feet. A small mountain stream runs by the camp, in a channel approximately fifty feet deep, and our kitchen and dark room tents were located in the valley close to the stream. As a side matter I may state that this stream was well stocked with fine speckled trout, which was quite an important matter for our commissary department.

The high mountain in the central background of the picture, known as Mt. Henry, is between five and six miles distant. The top is a ridge nearly a mile long and very narrow. The general altitude of the ridge is about 8,400 feet and the sharp peak at the left end is about 8,850 feet above sea level. The round peak to the right and in front of Mt. Henry is a little over four miles distant and about 7,800 feet above sea level.

We should have liked to establish our station on one of these peaks, but the difficulty of transporting our heavy apparatus and supplies and the necessity of permanent shelter which would cost much more than our funds would warrant, prohibited the entertainment of such a desire. During August, when the smoke from forest fires filled the valleys and shut us off entirely from our work, we often wished we could have been located on the highest peak, which on the day we ascended it was quite free from smoke while the valleys were full.

The summits of these mountains are bare of vegetation, with the exception of some small mountain flowers and mosses which grow between the pieces of broken rock. Fuel and water would have to be carried up from one to two thousand feet.

Starting from Northfield on the morning of June 30, we had a delightful trip across Minnesota, North Dakota, and Montana, reaching Midvale on the morning of July 1. The drop off here was something of a shock, although we knew what to expect, for there is no village,—nothing but the necessary railroad station houses for telegraph operators and section hands, with one ranch in sight. After a few hours spent in examining the ground we selected our location and began to set up camp. On July 8 the instruments were in adjustment and the first photograph was taken on that night.



THE CAMP OF PROFESSORS PAYNE AND WILSON AT MIDVALE, MONTANA.

The telescope and cameras, as set up at the camp, are shown in Plate XX. The day on which this photograph was taken, our last day but one at camp, was very smoky, so that the mountains are scarcely visible in the background.

We took with us the entire outfit of our 8-inch photographic telescope, with attached cameras, except the pier on which it is mounted. In place of the pier we set up two 10x12-inch pine timbers seven feet long, setting them 3½ feet in the ground and boxing in between them a well for the fall of the clock weight. These timbers formed a very steady support for the instruments and seemed to remain quite stationary during the two months although they were newly sawn out of green wood. In the engraving the reader will readily recognize the two telescopes of equal length, the 6-inch camera, of 36 inches focal length, projected in the picture against the lower part of the guiding telescope, and the 2½-inch camera, attached to the larger telescope near the upper end.

The telescope, as shown in the picture, was entirely out of doors and the only protection for it was an oilcloth cover which was wrapped carefully about the instrument when it was not in use. Fortunately there were no violent storms and very little rain during the two months. Fully half of the nights in July and nearly all of those in August were clear, except for the smoke from the forest fires. On every clear night the air was exceedingly quiet so that the telescope was seldom disturbed by a breath of air. During the day the wind was frequently quite strong and on a few cloudy nights it was such as to prevent our sleeping well in the tents. Several times the clouds which were running thick during the day would clear away just before the time for us to begin work at night and come on again in the morning. A very marked phenomenon on a few nights was the dissolving of great clouds, which rolled over the mountains toward us threatening to stop our work, but which entirely disappeared before reaching the zenith.

As a rule the ordinary clouds ran much higher than the mountain tops,—several thousand feet higher, I should judge,—but on two or three occasions when the weather was stormy they enveloped the mountains and sometimes detached clouds floated through the passes about 2,000 feet below the highest peaks. Twice fresh snow was deposited on the higher mountains, and once a tornado was seen passing several miles away.

Judging by the naked eye views of the sky the atmosphere ap-

peared strikingly more transparent than it does ordinarily at Northfield. Many more stars were visible at a glance, and the familiar stars appeared more brilliant. Near the horizon the difference was very marked, but perhaps that does not give a fair comparison, for the horizon all around us was elevated some degrees. In the direction of the mountains the elevation was over seven degrees.

During the clear days one could look close to the edge of the Sun and not notice much glare around it. The Moon stood out sharp and distinct so that some of the familiar craters could be recognized with the naked eye. The Milky Way stood out more in relief, the great patches being broken up into lesser ones more noticeably than here at home.

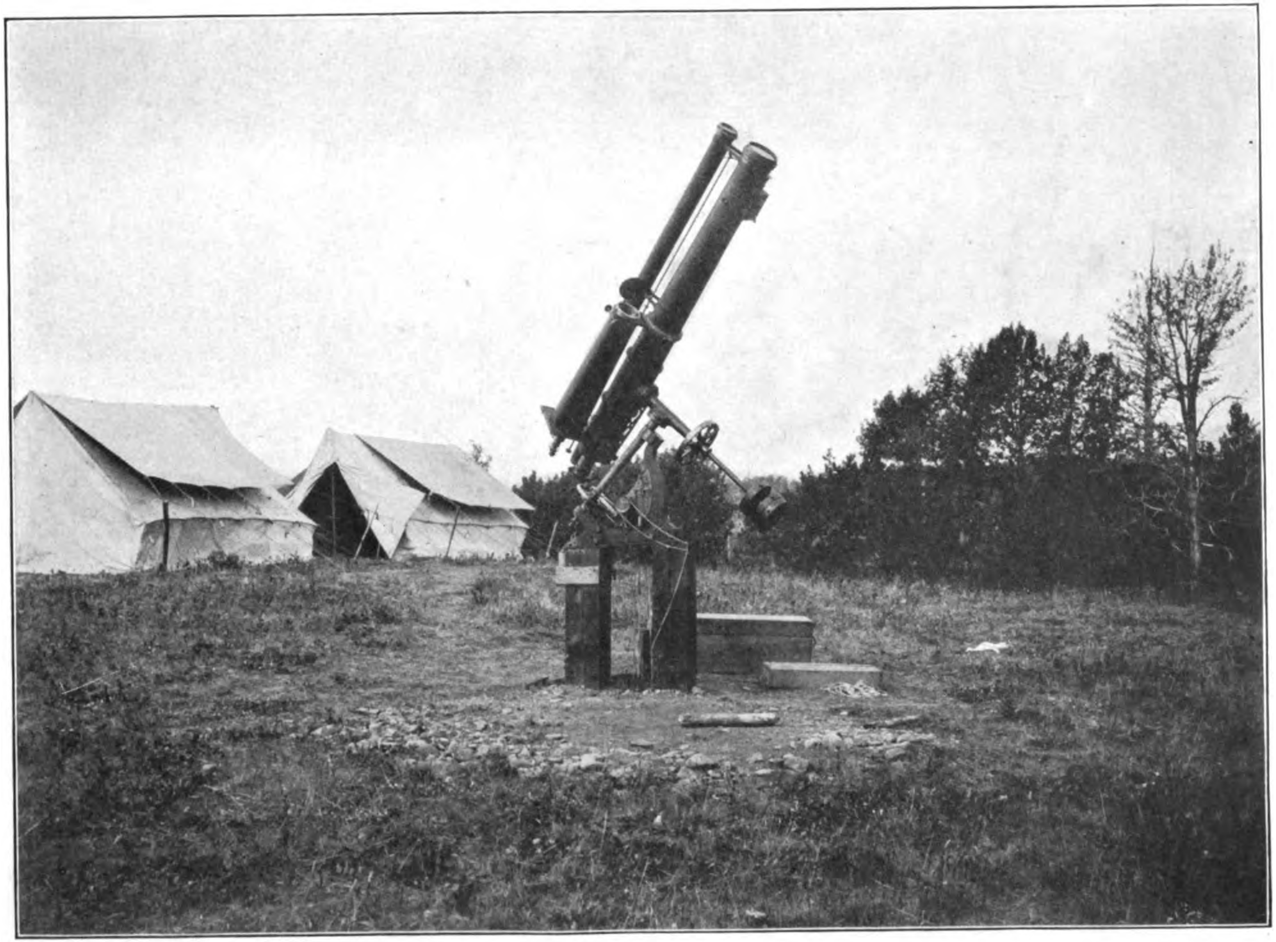
The color of the sky instead of being darker, as was anticipated from there being less suspended matter to reflect diffused starlight, was of a perceptibly lighter blue. The increased brightness of the sky did not, however, seem to diminish the apparent brilliancy of the stars. The impression given the writer was that of space not empty but filled with faintly luminous matter, not uniformly bright but with slight variations all over the regions distant from the Milky Way, and everywhere exceedingly transparent to the light of the stars.

In the great bright cloud of the Milky Way between β and γ Cygni one could count easily 16 or 17 stars besides the bright ones η and χ, while at Northfield it is difficult to distinctly see 8 or 9 with the naked eye.

Our first photographic experiments were upon the familiar object known as the America Nebula in the constellation Cygnus. This is a large diffuse nebula in the bright patch of the Milky Way about 3° east of α Cygni. It has been several times photographed by Wolf, Roberts and Barnard, and there are several excellent reproductions of it in *Knowledge*, notably the numbers for October and December, 1891 and July, 1902*. It was named the "America" Nebula by Dr. Wolf, who noticed on his first photograph of it, on Dec. 12, 1890, a striking resemblance between its outlines and the map of North America. The writer also had obtained photographs with both the 2½-inch and 6-inch cameras on the night of June 21, 1895, with an exposure of four hours, so that it is quite a fitting object for the purposes of comparison as well as being in one of the regions described by Herschel as filled with very extended nebulosity.

* See also *Monthly Notices R. A. S.* Nov. 1902, and Celestial Photographs by Isaac Roberts, Vol. II., Plate 24.

PLATE XX.



THE 8-INCH PHOTOGRAPHIC TELESCOPE AND ATTACHED CAMERAS AS MOUNTED AT MIDVALE, MONTANA.

PLATE XXI.

N.

S.

THE MILKY WAY BETWEEN γ AND β CYGNI.

Photographed with a 2½-inch Darlot Lens at Midvale, Montana. Exposure 2 hours.

The negative from which Plate XVIII was prepared was obtained at Midvale, Montana, July 9, 1904, with a 2½-inch Darlot lens and three hours exposure. The reproduction is enlarged to nearly three times the scale of the original and only the central portion, which is comparatively free from distortion, has been included in the engraving. The area of sky covered in the engraving is about 14° long and 10° wide. The bright star image 1½ inches to the right from the center is that of α Cygni. The star ξ Cygni is in the dark space to the left of the nebula, about ⅜ inch below and ¼ inch to the left of the center; ν Cygni is an inch below the lower point of the "America" nebula, π^2 is just at the upper left hand corner of the engraving, while γ lies quite a little outside the lower right hand corner.

Not only is the region having the shape of North America full of nebulosity but a large area to the west of it is strewn with patches of faint light, and to the north and northwest it is impossible to tell where the nebula ends in the mass of faint stars. To give an idea of the faintness of this nebulosity let me say that an equally strong image of the outer loops of the Orion Nebula can be obtained with the same lens with an exposure of less than ten minutes.

More striking even than the nebula and the cloud of stars are the dark spaces and lanes or channels in the midst of the star masses. One of the darkest spaces of the northern half of the Milky Way lies just at the left of the "America" nebula. It is very conspicuous to the naked eye on any clear moonless night just now, being overhead in the early evening. Two rather bright stars lie close to its center line but faint stars are remarkably few. At the right of the nebula the spot corresponding to the Gulf of Mexico, in fact the whole "Atlantic coast line," is remarkable for the absence of stars. On the north is a row of approximately parabola shaped bays encroaching upon the nebula and the star cloud and connecting with them a crooked dark channel runs to the north edge of the plate. Across the left hand portion of the plate are other remarkable arrangements of star clouds and dark channels which are well worthy of study.

At Midvale three photographs of this region were taken with the 2½-inch camera with exposures of one, three and four hours respectively. Plates were exposed at the same time in the 6-inch camera and the 8-inch telescope. Unfortunately in handling the large plates exposed in the 6-inch camera, in the small and inconvenient developing box which we had at the camp, I at first fogged them slightly, so that they are not suitable for reproduc-

tion, and the scale of the picture given by the 8-inch is too large for such faint nebulosity to make much impression on the plates.

The three plates exposed in the 2½-inch camera are all good and show the same general outlines of the nebula. The density of the negatives seems about proportional to the duration of exposure. With the longer exposures the fainter portions of the nebula are filled in and the outlying patches are enlarged. Both the three and four hour exposures appear to give all of the nebulous area shown in the reproduction of Dr. Wolf's photograph in *Knowledge*, Dec. 1, 1891, which was taken with a portrait lens and an exposure of thirteen hours.

My first impression on developing the one hour exposure was that it was equal to the four hour exposure at home, but a careful comparison of the plates shows that the gain is not nearly so great. At first sight the three hour photograph at Midvale appears to be equal to the four hour at home. There is a slight difference in the development of the two negatives, and allowing for this I conclude that one hour of exposure at Midvale will give about the same result as two hours at Northfield.

I reach the same conclusion by comparing a two hour exposure made on the great star cloud between β and γ Cygni made at Midvale with a four hour exposure made at Northfield in 1894 and one of two hours made since our return, with the same instrument. A comparison of the photographs taken with the 6-inch Brashear camera confirms the conclusion that in the increase of altitude of nearly 4,000 feet there is a decided gain in the impression made upon a photographic plate by stars and nebulæ with a given duration of exposure.

Plate XXI has been prepared from a negative exposed for two hours, at Midvale, on the night of July 20, 1904, with the 2½-inch Darlot lens. In reproduction the photograph has been enlarged nearly three diameters and only the central portions are retained in the engraving. The area of sky covered by the engraving extends from near β Cygni at the lower right hand corner to near γ Cygni at the upper left hand corner, thus including the major part of the great star cloud of the Milky Way lying between the two stars named. Neither of these stars are included in the picture, γ lying ¼ inch above and ½ inch to the right of the upper left hand corner and β being ⅔ inch below and an inch to the left of the lower right hand corner of the plate. Within the area shown Heis' Atlas gives 2 stars of the fourth magnitude, 12 of the fifth and 17 of the sixth. It is, however, difficult on an ordinary night for a person with average eyesight

to distinguish more than 8 or 10 of the stars, the fainter ones being hidden in the glow of the thousands which are just a little beyond the limit of vision.

In this great star cloud too are seen the curious dark patches and lanes, to which attention was called on Plate XVIII. Two explanations are offered for these, the one that they are really, as they appear, vacant spaces void of stars, through which we see into empty space beyond, the other that they are produced by the intervention of enormous clouds of dark matter between us and the stars of the Milky Way, absorbing and cutting off their light. The latter view was strongly advocated some thirteen years ago by Mr. A. C. Ranyard, then Editor of *Knowledge*, but is not generally accepted among astronomers.

During our stay at Midvale, we made exposures, on two nights each in July, on Herschel's regions Nos. 43 and 45, α 20^h 53^m 15^s, $\delta + 16° 44'$ and α 20^h 57^m 34^s, $\delta - 1° 34'$ and also, on two fairly clear nights in August, on the region No. 48 near ϵ Pegasi. The plates all show feeble variations in density of the skylight in the regions indicated by Herschel, but we have not yet found time to copy them and bring them out with sufficient intensity to decide whether the duplicate plates agree in detail or not. We hope to find time to make this test during the coming month.

THE MATHEMATICAL THEORY OF ECLIPSES.

WM. W. PAYNE.

"The mathematical theory of eclipses according to Chauvenet's transformation of Bessel's method, explained and illustrated" is the full title of one of the most important and useful books for the student in practical astronomy that has been published in many years. The author of the book is Roberdeau Buchanan who was assistant in the Nautical Almanac Office, Washington, D. C., for twenty-three years and is also author of a small book, titled "A treatise on the Projection of the Sphere." The publishers are J. B. Lippincott Company, Philadelphia.

This new book which bears impress of March 24, 1904, contains 247 pages, finely printed on heavy book paper, in clear type of about the same size as that used in Chauvenet's Spherical and Practical Astronomy, published more than forty years ago by the same well-known printing house. Its indexes, tables and illustrations are evidence that its author knows well, in the line of this work, how to arrange reference matter for the con-

veniences of a hand book, that seems to leave little or nothing for the most exacting of the mathematicians to desire. We are very agreeably surprised at the thoroughness of detail and the completeness of the work as an aid for self instruction in the study and computation of solar and lunar eclipses, transits of Mercury and Venus and the occultations of the fixed stars. Chauvenet's Spherical and Practical Astronomy is incomparably the greatest work, on this subject, that has ever been published in the English language. Like other great authors in mathematics, Chauvenet is not always clear and definite and complete in the discussion and illustration of sound theory. Analytic powers of mind of a high order easily make long steps in legitimate argument, that can not readily be followed by those who have less experience or less mental grasp naturally. After more than a score of years of experience in computing eclipses for the Nautical Almanac, in which time, the author of this new book must have gone through the whole cycle of eclipses belonging to one Saros, he certainly has had the opportunity to gain a knowledge of details which can possibly come to no one else who has not studied this matter in the same way.

In view of these facts we have read this book through somewhat carefully and have compared the positions taken by the author with those made by Chauvenet in his Astronomy to satisfy ourselves that the important claims made in the book before us are well supported in fact.

Some of the points made by the author are that the theory of eclipses is one of considerable intricacy, and while the student can generally follow Chauvenet in deducing the formulæ, yet he meets with some difficulty in grasping the subject, finding many points requiring further explanation than is given in the text. Whenever this occurs no other publication will be of the least assistance in explaining this part of Chauvenet's work.

Another difficulty is met by the practical computer, however well skilled he may be in formulæ or computing, and that is, the formulæ of Chauvenet are not developed in the order they are to be used in computing eclipses. They are so numerous and so scattered that it is necessary to write them out in order before the computation of an eclipse is undertaken.

Again in Chauvenet's elegant treatise the formulæ are so rigorously exact, that many of them may be considerably simplified and the labor of using them thereby diminished. It is useful and encouraging to know when and how such work may be done. The author has undertaken to do this in some cases and

he plainly indicates the advantages arising from such steps.

One of the most impressive features in this new book is the use of graphic method employed in explaining complicated formulæ. We have nowhere else seen the use of this method so fully and effectively given as in Mr. Buchanan's work. Modern mathematics for the last few years has been emphasizing this way of presenting the results of intricate problems, in different lines of scientific research especially where lines and curves of continuity play some important or unique part.

This new book seems to us to deserve a fuller notice than the general statement we have already made, that our readers may know somewhat more in detail the features of it and the ground it covers. The first section speaks of the two methods of computing solar eclipses, that have been in use; the first and the earlier considered the Sun and Moon as tangent to one another externally, and the distance between their centers was the arc of a great circle equal to the sum of their radii. By this method, given the place of the eclipse, find the times. Only one place on the Earth's surface could be used in computation at once. The second method was exactly the converse of this: given the time, and the place on the Earth's surface where the phenomenon is seen will be found. In other words assume a series of times, and all the points on the Earth's surface where the same phenomena are visible may be made known, an advantage not possessed by the former method. Those acquainted with the history of this subject will remember that the genius of Bessel in 1841-42 planned and devised the remarkable formulæ that have been accepted as the best for the last sixty years and more. Hansen in 1858 presented a different method, but Professor Chauvenet in 1863 said: "As a refined and exhaustive disquisition upon the whole theory "Bessel's *Analyse der Finsternisse* in his *Astronomische Untersuchungen* stands alone." It might be expected from Chauvenet's opinion of Bessel's work, that he would make it the basis of his own standard works in astronomy that were published later; and, since this new book makes Chauvenet the basis of its plan and general methods for the computer, it would be expected that about the same order would be followed here. So in the second section the criterion of the solar eclipse is considered, and specific directions are given for interpolation, even to the logarithms to be used in computing first or second differences.

We notice with interest what is said on page 27 about I, the inclination of the Moon's orbit to the Ecliptic. Chauvenet does not show how to get that quantity, neither does the Nautical

Almanac give it, but, in a few words this author's suggestions plainly open the way for a student without experience.

This author thinks that the values given by Chauvenet on page 438 of his Practical and Spherical Astronomy need revision, the Moon's least parallax being in error at least one minute. The author comes to this conclusion after consulting Professor Ruel Keith who has computed the Moon's semi-diameter and parallax for the Nautical Almanac for thirty consecutive years, who said: "the Moon changes its distance so irregularly that it is hard to follow it by rule," and the author says "I then take the extreme values of the Moon's parallax from all the eclipses I have computed from 1883 to 1905, both years inclusive. * * * These extremes may not be the greatest possible, but they are at least better than those heretofore given as correct, for the greatest value is greater than that given by some authorities, and the least value is less." Then he gives a table of values of these quantities, from many authorities that have claimed attention during the last fifty years, showing why particular values have been chosen.

Speaking of the Saros in connection with the criterion, the author calls attention to a misprint in Newcomb's Popular Astronomy, 1878, p. 30, which gives the length of the Saros as 19⅔ years when it should be 18⅔. The suggestions at the close of the section for making a search for the eclipses of a given year are helpful and apparently complete.

In section third the reader will find the data and the elements for the solar eclipse taken up in an orderly way. The example given is the total solar eclipse of 1904, September 9. The six quantities required for all eclipses are first mentioned and they are interpolated by the usual formula to first, second or third differences, as is needful for them respectively to fulfill the part of the work necessarily dependent on them. In his remarks on this first step of the computation, the author calls attention to a principle in the theory of differences which seems to have been overlooked in ordinary works on interpolation. It is regarding the quantity Δ, that it is distributive in differences of right ascension of the Sun of any order. This fact may be made use of as a check in numerical operations, as well as a means of shortening the work in certain methods of computation. A similar statement may be made about the Moon's declination.

Attention is also called particularly to the eclipse constants, the Sun's parallax and semi-diameter, the ratio of the Moon's equatorial radius to that of the Earth and irradiation. The

authorities for these constants are given, when they came into use, how almanac officers in England and America have changed them and used them in recent years.

Section four has to do with the eclipse tables, and it is a very important part of the book which precedes the commencement of the work for the eclipse itself. The computer is told how to use the constants in actual work, how to employ the Zech's tables of addition and subtraction, logarithms expeditiously and a great number of other details that is helpful for any one to know if he would use the best ways of computation only to a limited extent.

The author has carried the example before mentioned through all the details of this table work, to illustrate in the best way possible just what he means in a real case of computation by the verbal descriptions in his text. At the close of this section he tells how to illustrate the eclipse generally by geometrical methods and gives a full page plate of the drawing belonging to the example in hand. His methods of projection are full and clear and seem well adapted to the matter in hand.

In working out this particular eclipse in detail, the author refers to a great number of other eclipses which he has computed to show how the work will vary in these different cases and he remarks distinctly where exceptions to general rules must be made. We have been impressed by the knowledge that the author shows in the descriptive part of his book about the whole theory of eclipses, as presented in the details of computation to reach the varying conditions that must be met in going through a whole cycle of eclipses in a single Saros. The attention that is given to details in this matter goes so far as to call the attention of the student to the fact that it is necessary to avoid mistakes in regard to signs for algebraic operations in particular cases, also giving instruction in regard to the signs that belong to the quantities as such.

We notice with satisfaction and interest that the plan of the author in his illustrative examples is that which is in use by the best practical and experienced computers with whom we are acquainted. First to write out all the formulæ needed for a particular part or step in the solution of a problem, and then to put the terms to be computed in vertical columns with the number of the formulæ in the first, and the quantities in the next, and the signs of operation and of character with the logarithms in another column, so that every part of the work is as orderly and definite as the most logical verbal argument could be if con-

structured by a masterly logician. Every experienced scholar in the higher mathematics knows that this is the way to write mathematics so that any one may read the work of a computer as he would a printed argument from a lawyer's brief or a story written by a novelist. Putting mathematical arguments in this way makes the writer or reader to understand just what he is doing, and why he is doing it. This is mathematical training in the largest and best sense. In the choice of logarithmic tables for the computing part of the work, the author has made some excellent suggestions, the substance of which, we know, have been overlooked by some good scholars and teachers in very recent years. As before indicated, in a single sentence, so now in all parts of the illustrative example of the eclipse of 1904, September 8, the author decides what tables as to number of decimal places in the mantissa should be used, and gives his reasons for the suggestions made in this particular. Not long ago a student who had received some instruction at Goodsell Observatory in computing the orbits of comets, and who later attended one of the largest and most popular Universities in the United States, wherein special courses in practical astronomy are advertised and taught, did further work in the same lines in that Institution. Any practical computer can well imagine that student's surprise when directed by the instructor to use seven-place tables for some work on a comet orbit, in regard to which four-place logarithms would have been much better every way. It is just such practical and useful and time-saving knowledge as this that the student wants and should have in preparation for rapid and efficient work in any scientific pursuit.

Another of the strong points in this new book which ought to be referred to more fully is the use that the author makes frequently of graphic illustrations in the course of explaining the meaning of intricate formulæ. It is one thing to take a formula as it may be given by an author, and compute a problem by it accurately, but it is quite another thing to do the same work in the same way, having fully understood beforehand the full meaning of the analytic structure of the equations that are being so used. These geometrical figures and the full explanations that accompany them not only give the student a full and clear meaning of what the author has been doing and what he himself is trying to do, but they add to and maintain his own interest while he is pushing his way through mazes of analytical transformations which often trouble good mathematicians to understand unless by some such aid as that furnished by graphical

methods. We earnestly commend this excellent feature in this new book.

In Section twenty on the shape of the eclipse shadow on the Earth, several things are found worthy of especial notice. It is as a whole mathematically one of the strong parts of the work. In the beginning of this section is given Professor Bigelow's theory of the "shadow bands," so-called, which are usually seen near the beginning and end of totality in solar eclipses. After a study of the total eclipse of May 28, 1900, Professor Bigelow of the Weather Bureau, Washington, came to the conclusion that these "shadow bands," were caused by the undulations and disturbances of the density of the atmosphere within the cone of the shadow due to the lower temperature within the cone which may fall five or six degrees thereby producing intermittent opacity. So far as we know this explanation of that curious phenomenon of the shadow bands is new. Astronomers generally have not been agreed as to their cause, but they have commonly attributed this display of color to the effect of diffraction of the Sun's light as it passes by the limbs of the Moon, a very natural inference, but so far lacking the sufficient observational proof to warrant acceptance.

We think enough of this new book to adopt it as one of the hand-books of reference in the post-graduate course of study in Mathematics and Astronomy at Goodsell Observatory which will soon be opened again for students wishing to prepare themselves for instruction in either Mathematics or Astronomy, or for places in Observatories contemplating either oversight of such institutions or practical work therein.

PHOTOGRAPHY OF THE HEAVENS.*

On the Accuracy of the Positions of the Stars Obtained by Means of Photography. Notes of G. Boccardi. Communicated by Correspondent A. Riccò.

Every one knows that the application of celestial photography to the compiling of star catalogues has notably shortened the labor; but perhaps all have not realized the degree of exactness which can be secured in the photographic positions of the stars, a degree which is far superior to that of the positions given by the better catalogues and depending on many meridian observations.

The illustrious Monsieur Loewy in various memoirs recently published has examined and discussed the different causes of

* Translated by Miss Lucia E. Danforth, Red Wing, Minn.

error, which, although in a slight degree, exist in the photographic positions of the stars. The conclusion at which he has arrived in the above-mentioned memoirs in the Introduction to Volume I of the Photographic Catalogue of Paris is that in the error which remains in the photographic positions of the stars are involved the following factors:

1st. The inexactness of the measures of the rectilinear co-ordinates of the stars on the plate.

2nd. The inexactness resulting from the nature of the thin gelatine film which covers the plate; that is to say, of its varying degree of sensitiveness in the extention of the single squares of the reticule impressed on the plate and the irregularity which the film shows. According to Loewy the error produced by this physical cause in the measurement of the co-ordinates is hardly appreciable above the tenth magnitude but for the stars below the tenth magnitude it is appreciable, and about equal to the error arising from the same measurements, and it increases rapidly as the size diminishes.

3rd. The uncertainties which remain in the adopted positions in equatorial co-ordinates for the comparison stars selected on the plate to determine the constants and the corrections to the measures.

Being charged with the reduction in the stellar catalogue of the celestial photographs obtained in the Royal Observatory of Catania, by the Director, Professor Riccò, and by the engineer, Signor Moscari, I have had occasion to occupy myself also with the degree of accuracy which can be obtained in the photographic stellar positions. To determine this accuracy I have preferred a practical method, the general principle of which consists in comparing the divergences between the photographic position of a star given by the different observatories with the divergences between the positions of the same star given also by the different observatories and depending on observations of the meridian circle. In making the comparisons between the photographic and meridian divergences I do not take up mean or probable errors of the two classes of measurements, because, if through the meridian positions it was possible to calculate the errors according to the method of least squares, having many meridian positions of the same stars, given by different observatories, this was not possible through the photographic positions, since the same star has rarely been photographed at several different observatories, and the photographic results have rarely been published. In fact, I have not been able to institute a com-

parison except between two, or at most, three, photographic positions of the same stars. I have therefore believed it preferable to calculate through the two kinds of measurement the differences from the mean and to compare them with each other.

With regard to the meridian positions Monsieur Loewy, basing the calculation on all the meridian positions of 21 reference stars for *Eros* has calculated the following probable errors:

in α $\pm 0''.350$ in δ $\pm 0.''332$

But this result is not general, as the probable error varies much according to the stars and also differs slightly with the declination. It may be seen that in 42 stars of *Eros*, employed by me in one of the proofs made, we have through the average difference of one meridian position given by one observatory from the average of all the positions given by many observatories

in α $\pm 0''.69$ in δ $\pm 0''.36$

In another group of 18 stars of *Eros* I find average difference:

in α $\pm 0''.84$ in δ $\pm 0''.42$

The comparison of the differences relative to the photographic and meridian positions can be made through every star in particular, and then the influence of the magnitude disappears; that is one can have in every magnitude an exact idea of the accuracy of the two methods. Besides, having compared the positions of about all the stars below the eighth magnitude and above the tenth magnitude the average of the differences for the different stars can give an exact idea of the degree of precision which can be obtained with such small stars. As the meridian positions of every star for Eros given by the different observatories are based on nearly the same number of observations I have not paid any attention to the smaller differences which can be obtained from a diversity in the number of observations.

I refer here only to a few of the many experiments made by me to determine the accuracy of the photographic positions.

I. I have compared together the photographic positions of 42 comparison stars belonging to the plates of the Observatories of Paris and Bordeaux taking the relative data of circular No. 10 of the Observatory of Paris. The stars were DM 53^0,470 and these following in the Circular (p. 162) as far as 52^0,609. I have calculated the differences in α and δ between the photographic positions given at Paris and those given at Bordeaux. Without recourse to squares I have formed the arithmetical mean of the absolute differences in α and δ obtaining the respective values $\pm 0^s.0210$ and $\pm 0''.197$.

The difference of one photographic position from the mean of two photographic positions is half of these values, that is $\pm 0^s.0105$, $\pm 0''.0985$. Continuing this process for each of the forty-two stars I have formed the differences between the meridian positions given by the different observatories and the mean value; that is the average of these positions (as has been calculated at Paris) and in the same manner as through the photographic with each of these stars I have calculated the average of these differences, dividing, that is, the sum of the differences of the average taken in absolute value, by their number.

Adding all these averages of the relative differences for all of the 42 stars, I have divided the sum by 42 and have obtained thus through values of the differences of one meridian position from the mean $\pm 0^s.0461$, $\pm 0''363$.

Inasmuch as the photographic positions given by the two observatories as well as the meridian positions furnished by many observatories were obtained at the same time, that is in the second month of the year 1900, a comparison between the results of the two methods is legitimate. Then, since the average differences obtained as above are approximate to those which are obtained by using the squares if it is believed that by applying also in this case the criterions of the method of the least squares, to judge of the relative exactness of the two kinds of measurement, one will find that in the case cited the exactness of the photographic positions is in α more than 16 times as great as that of the meridian positions; in δ a little less than 16 times as great. But this proportion varies with different cases.

II. The second proof which I give is based upon a consideration of a somewhat different character, that is to say by comparison of the maximum difference from the several photographic positions of a star with the maximum difference from the meridian position given for the same star by different observatories. I have by my method reduced the plates Nos. 775 and 1856 of Catania comparing nine stars and for each of these stars I have adopted for the photographic position the average of the results of the two plates. As the photographic positions of these nine stars obtained at Paris are given in the Circular quoted and for four of these also the positions obtained at Bordeaux I have for each star compared together the photographic positions of Paris, Catania and Bordeaux, when they existed, and written for all the nine stars the greatest difference between the photographic positions of the Observatories mentioned. I have afterward in another place compared together

for each of the nine stars the meridian positions obtained in different observatories, on occasion of the observations of *Eros* and also written for each star the maximum divergence.

The results are found in the following table in which the small numbers written below the seconds of the right ascension photographed at Paris, Bordeaux and Catania, indicate the number of the plate on which the photographic position depends:

DM No.	Photographic Position for 1900.0 Paris	Bordeaux	Catania	Diverg. Photograph.	Diverg. merid.
°	h m s	s	s	s	s
+48,746	2.37.22,085 (2)		22,073 (2)	0,012	0,06
+48,750	" 38.56,222 (5)		56,244 (2)	0,022	0,15
+48,760	" 41.25,413 (4)	25,398 (5)	25,396 (2)	0,017	0,06
+47,700	" 41.43,828 (5)		43,840 (2)	0,012	0,23
+48,762	" 42 1,295 (4)	1,274 (2)	1,267 (2)	0,028	0,18
+48,763	" 42.27,528 (5)	27,523 (5)	27,498 (2)	0,030	0,28
+48,764	" 42.43,272 (5)		43,241 (2)	0,031	0,12
+48,770	" 44.19,649 (2)	19,659 (4)	19,649 (2)	0,026	0,33
+47,714	" 44.39,926 (4)		39,926 (2)	0,017	0,09
			mean	±0.0217	±0,167

Photographic Position for 1900.0 Paris	Bordeaux	Catania	Diverg. Photograph.	Diverg. merid.
° ′ ″	″	″	″	″
48.48 20,30		20,58	0,28	1,2
48.32. 8,16		7,98	0,22	1,2
48.48. 6,30	6,21	6,51	0,30	0,9
48. 2. 9,92		9,64	0,28	1,2
48.45.58,93	58,77	59,44	0,67	0,8
48.53. 4,87	4,55	5,14	0,39	1,2
48.27.49,24		49,21	0,03	1,2
48.56.10,40	10,07	10,58	0,51	1,4
48. 5.32,45		32,22	0,23	1,4
		mean	±0,346	±1,167

The meridian divergences are given with one cipher less, because the positions given by the different observatories come in the end to about the same result. The error of the photographic positions of Bordeaux for five of the nine stars can not perhaps be found

by the method which follows, because the positions of Catania being based upon only two plates obviously preclude the possibility of having the highest divergency determined from them. It is proved partly by the preceding table but more by comparing the photographic positions of Paris and Bordeaux through the whole series of stars of Circular No. 10, through which generally the divergencies are less than those resulting from the nine stars between the two observatories.

The preceding table establishes the fact that the average of the highest divergencies between the photographic positions is in α nearly eight times less than the corresponding average in the meridian positions. In δ it is more than four times less. Thus the great superiority of the photographic positions over the most exact meridian positions is evident.

III. Another important fact which results from a comparison of the photographic positions with these, is that the accuracy of these increases a little by multiplying the number of the plates on which they are found. This may be gathered from the preceding table, but more by comparing the photographic positions of Paris and Bordeaux relating to the forty-two stars which we have mentioned.

From these, to cite several examples, it is seen (Circular No. 10, p. 163) that for one star the photographic position of Paris based on twenty-five plates differs from that of Bordeaux based on seven plates, by $0^s.023$, $0''.003$: for another star the positions of which depend respectively on 28 and 10 plates, the differences between those given by the two observatories are $0^s.012$, $0''.028$. On the other hand for one star based on three plates in Paris and three in Bordeaux, the differences are scarcely $0^s.012$, $0''.19$ and such examples can be multiplied.

I have found a confirmation of this fact in the examination of the differences existing between the meridian positions adopted for the stars of comparison and the photographic positions of the same stars. In fact if we compare the given results through the stars reduced in the different observatories with a much different number of plates, we find that these results are not much different from each other. Therefore it is of little assistance to multiply the number of plates on which the photographic position is found.

Not to have recourse to other examples, I give in the following table for the nine stars of which I have before spoken: The residual differences, the meridian position, the photographic position, for Paris, Bordeaux and Catania. It should be noted that the

meridian positions for which I have compared the photographs are those adopted respectively in those three observatories. Also in the following table the small numbers written under the seconds of the right ascension indicate the number of the plates on which the respective photographic position depends. It should be noticed also that the rectilinear co-ordinates of the stars on the plate were deduced at Paris from the measurement of the two photographs of any star each measured two times and these four measurements were repeated in four orientations, differing by 90 degrees. The co-ordinates of Catania depend on the measure of one photograph alone made only one time in one position and another time in a position at an angle of 180 degrees.

Differences between the meridian and photographic positions.
(Sign: merid.—photograph).

through α			through δ		
Paris	Bordeaux	Catania	Paris	Bordeaux	Catania
s	s	s	"	"	"
+ 0,053 2		+ 0,049 2	+ 0,07		+ 0,19
— 0,017 5		0,000 2	— 0,14		— 0,41
— 0,011 4	— 0,025 5	— 0,035 2	— 0,03	— 0,13	+ 0,10
+ 0,008 5		+ 0,019 2	— 0,10		— 0,36
— 0,020 4	— 0,032 2	— 0,046 2	+ 0,15	— 0,04	+ 0,55
+ 0,009 6	+ 0,008 5	— 0,019 2	+ 0,08	— 0,10	+ 0,23
— 0,007 5		— 0,047 2	— 0,19		— 0,25
+ 0,005 2	+ 0,011 4	— 0,021 2	+ 0,50	+ 0,33	+ 0,73
— 0,021 4		— 0,047 2	+ 0,03		— 0,26

IV. The last comparative table which I consider, refers to the photographic and meridian positions of eighteen stars by comparing Plate No. 2057 of Catania. Of these same stars we have only the photographic positions obtained at Bordeaux, not with one plate alone as in Catania, but with several. The stars given were not photographed in Paris. In the following table I give for every star the differences from the photographic position given by the two observatories and afterward the maximum differences from the meridian positions given at the several observatories, naturally, because the comparison of the two classes of measurements to be legitimate would have to compare the photographic positions not of two observatories but of several.

Therefore, it has not been possible for me to obtain the data necessary for that. In any case it may be deduced from the preceding tables that the maximum photographic difference, in case of many observatories would not be preceptibly greater than those from the positions of Bordeaux and Catania, the highest differences of which are caused partly by the difference in times at which the plates were photographed. In fact the average period of the Bordeaux plates is 1900.8, while the Catania plate was taken by Professor Riccò, August 28, 1903. The meridian plates, however, between which I give the maximum differences, all refer to the same period.

D. M.	Photographic Position for 1900.0 Bordeaux	Catania	Bordeaux	Catania	Difference Bordeaux	Catania	Maximum diverg. from the meridian position	
°	h m s	s	° ′ ″	″	s	″	s	″
51,317	1.24.26,147$_{3}$	26,135	51.34.41,71	41,35	+ 0,012	+ 0,36	0,17	2,6
49,401	24.37,849$_{2}$	37,821	50. 9. 7,16	7,30	+ 0,028	− 0,14	0,14	1,4
49,400	24.38,426$_{3}$	38,401	50. 5.56,10	55,81	+ 0,025	+ 0,29	0,15	2,2
50,297	25.41,687$_{3}$	41,693	50.55.13,84	14,82	− 0,006	− 0,98	0,13	1,1
50,298	26.12,652$_{2}$	12,714	50.38.51,85	51,90	− 0,062	− 0,05	0,13	2,2
50,299	26.22,631$_{2}$	22,648	50.18 34,51	35,04	+ 0,015	− 0,53	0,13	1,4
50,300	26.48,642$_{4}$	48,656	50.58. 5,01	5,10	− 0,014	− 0,09	0,30	1,5
50,301	26.59,920$_{3}$	59,945	50.22. 1,17	1,61	− 0,025	− 0,44	0,34	1,4
51,331	27.58,708$_{4}$	58,722	51.19.13,29	12,59	− 0,014	+ 0,70	0,12	2,5
49,414	28.19,574$_{3}$	19,582	50. 1. 1,62	1,92	− 0,008	− 0,30	0,23	2,1
51,334	28.33,783$_{4}$	33,808	51.38.28,99	28,55	− 0,025	+ 0,44	0,18	1,0
51,338	29.22,542$_{4}$	22,581	51.39. 7,87	7,25	− 0,039	+ 0,65	0,31	1,7
49,416	30. 5,718$_{3}$	5,705	50.12.23,77	24,43	+ 0,013	− 0,66	0,27	1,2
51,339	30.24,396$_{4}$	24,383	51.14.15,90	15,80	+ 0,013	+ 0,16	0,22	0,8
50,314	30.44,606$_{3}$	44,581	50.44.59,37	59,94	+ 0,025	− 0,57	0,21	0,6
49,442	31.42,180$_{3}$	42,178	50. 5.47,45	47,60	+ 0,002	− 0,15	0,24	3,4
51,357	33.13,708$_{4}$	13,651	51.45.32,45	32,19	+ 0,057	+ 0,26	0,33	7,9
51,363	34. 2,612$_{1}$	2,551	51.21.27,81	27,56	+ 0,061	+ 0,25	0,26	1,8
				mean:	± 0,0247	± 0,387	± 0,2144	± 1,711

Recapitulating, these are the principal conclusions at which we have arrived.

1st. If the rectilinear co-ordinate of only the larger image of a star (of the two images obtained in Catania) are measured in one position of the star, and if the measurement of the same image is repeated in a position 180 degrees from the first, the average of the values obtained by the comparison of the star in two positions of the plate is more exact than the average which would be obtained by always measuring in the same position two photographs of the star, each one twice, as is done, for example, at Paris.

2nd. Not having taken for examination stars of less than the tenth magnitude I have not been able to determine the error depending on the film of gelatine. However, although the fact that so far as the tenth magnitude the differences (relative to the same star) between the photographic positions obtained in the different observatories and the meridian positions are approximate seems to prove that so far as this magnitude the influence of the film is not appreciable, we can not admit that on the plates of the different observatories the effects of this cause of error are equal.

3rd. The accuracy of the celestial co-ordinates of the stars of comparison deduced from the plates, is always in the right ascension at least ten times as great as that of the positions depending on different observations of the meridian circle. Often the accuracy is more than fifteen times as great. In declination the exactness of the photographic positions is at least four times as great as that of the meridian positions. Often more than seven times as great.

4th. As a result of the investigations made in Catania and elsewhere, that the exactness of the photographic positions of the stars not used as reference stars to determine the constants of the plate is inferior to that of the positions of the stars of comparison, about in the proportion of one to two, one can say that the exactness of the photographic positions of a given star is in ascension at least five times as great as that of the meridian positions; in declination at least twice as great. It is well understood that this refers to the plates, the constants of which were determined by from ten to twelve comparison stars. From plates on which can be found twenty or more stars of comparison the exactness of the photographic positions is about the same for all the stars of the plate.

THE LEONIDS.

WILLIAM H. PICKERING.

FOR POPULAR ASTRONOMY.

It has already been shown in POPULAR ASTRONOMY, 1902, X., 8, 400, and 1903, XI., 6, that the maximum condensation of the Leonid shower, during the present thirty-four year period, was not due before 1901, and that it probably appeared in that year. The meteors then presented themselves in countless numbers as seen from the southern borders of the United States. It was also pointed out that while a considerable shower was to be expected in November for several successive years, that this shower would appear in different longitudes upon the Earth, the maximum density moving west about seven or eight hours each year. Thus for 1902 it was predicted for Japan, and for 1903 for Arabia and the Mediterranean. In 1902 no shower was recorded, but in 1903 a large number of meteors were observed in Greece and also in England. The English observers consider the shower of 1903 the finest of the present series. Mr. Denning states that at the maximum, the number of meteors visible to a single observer must have been in excess of 200 per hour, *Monthly Notices*, 1903, LXIV., 125.

At Harvard we have hitherto observed two maxima, one in 1898 and the other in 1901. Another is expected, therefore, this November. Whether it will equal or surpass the two others, there is of course no means of knowing. The results of the English observers might lead us to expect a considerable shower, since it was more than three times as dense as that of 1901 as observed at Harvard, while the latter was about twice as dense as the shower of 1898. On the other hand more brilliant firebells appeared in 1898 than in 1901. In any case nothing is expected to be seen before midnight of the night of November 14–15, and the greatest density is not looked for before 4 A. M. It is fortunate that there will be no Moon to interfere with the observations. While the writer is not prepared to predict anything more than a moderate shower, this letter has been written in order to warn observers who may be interested in such matters, that such a shower is due, and that it is possible that it may exceed in density anything that we have yet seen.

REDUCTION OF 295 PHOTOGRAPHS OF EROS MADE AT NINE OBSERVATORIES DURING THE PERIOD 1900 NOVEMBER 7-15, WITH A DETERMINATION OF THE SOLAR PARALLAX.*

ARTHUR R. HINKS, M. A.

§ 1. *Introduction.*—In two previous papers (*Monthly Notices*, 1901 November and 1902 June, vol. lxii. pp.22 and 551) there is an account of the experimental reduction of certain photographs of *Eros* made at Cambridge, Lick and Minneapolis. Its object was to test a method of reduction in rectangular co-ordinates; and the conclusion was that the method was simple, convenient, and worthy of a more extended trial. I therefore ventured to propose that we should undertake at Cambridge the reduction of so much of the photographic material obtained during the period 1900 November 7—15 as might be placed at our disposal by the kindness of the directors of the different observatories taking part in the co-operation to observe the planet *Eros* at that opposition. At the time this proposal was made we had very little information as to the real accuracy of the photographic method when pushed to the limit, and especially little knowledge of what systematic discordances might be found in the work of different observatories. It was hoped that the discussion of the material of these nine days, considerable in itself, but only a small part of the whole, might lead to a preliminary value for the solar parallax, of weight equal to that of the best existing values, and at the same time be some guide in the operations which must eventually be undertaken to combine the whole of the observations in one definite solution.

§ 2. The first step was to choose the stars which were to form the standard comparison stars.

For this system the stars of reference† selected by M. Loewy for special meridian observation are not suitable. They are chosen for plates 2° square, and in great part lie outside the limits of the smaller fields of many photographic telescopes; and they are on the average considerably brighter than the planet. A set of stars was chosen, including a few of these reference stars which lay near the track of the planet, and a number of others which were comparable in brightness with *Eros*, and evenly distributed, so that

* *Monthly Notices*, June, 1904.

† *Étoiles de repère.*

one might count on getting at least ten suitably distributed stars in any field with a radius of 15′. Photographic copies of a chart of these stars were sent to all the observatories who had photographs within the selected dates, with the request that in measuring their plates they should select from the list about ten stars, with the planet near the centre of gravity of the group, and should send to Cambridge a copy of the measured rectangular co-ordinates of stars and planet, uncorrected for anything except errors of the measuring machine and réseau.

§ 3. I must make grateful acknowledgement of the kindness with which this request was received. The directors of eight observatories have done me the honor of placing in my hands measures made under their direction, fulfilling in somewhat various ways the proposed conditions.

It will be generally convenient in what follows if each separate set of measures as communicated to me is called a plate, though in most cases a number of exposures were actually made on the same plate. The contributions were as follows:—

Algiers	measures	of	40 plates
Lick	"	"	28
Minneapolis	"	"	17
Northfield	"	"	23
Oxford (University Obs.)	"	"	32
Paris	"	"	21 (means of 3)
San Fernando	"	"	9
Tacubaya	"	"	15
These, added to			
Cambridge	"	"	110

make up the total of 295 discussed in the present paper.

Some more Oxford plates arrived unfortunately just too late to be included.

Each Paris plate is the mean of three separate exposures. On it are measured, in accordance with the Paris programme, all the stars of reference, and all the stars lying in a square of 20′ with the planet at its centre. A number of my standard comparison stars are found in this square, and some others are among the fainter reference stars. The average number of standard comparison stars on the Paris plates was 14.5.

The Algiers plates are measured on the same plan, but the exposures are single. The number of standard comparison stars measured on the Algiers plates was on the average 12.

On the San Fernando plates all the reference stars and all the stars in my list were measured. On the Tacubaya plates a large number of the stars in my list were measured. On the Lick, Minneapolis, Northfield, Oxford, and Cambridge plates groups of about ten stars were chosen from this list and measured.

The Algiers, Paris, and San Fernando plates are impressed with a réseau, but measured in millimetres; the Oxford, Cambridge, and Tacubaya plates are measured in réseau intervals (5mm.); the Lick, Minneapolis, and Northfield plates are measured in millimeters without a réseau. The Tacubaya plates were measured by estimation on an eyepiece scale, and the results will be comparatively rough.

§ 4. *Standard Centre.*—A feature of the method to be used is the transformation of every plate to the standard centre and standard axes of rectangular co-ordinates. The standard centre used in the experimental reductions was in R.A. $1^h\ 57^m\ 8^s{\cdot}0$, Decl. $+\ 04^\circ\ 22'\ 0''$ (1900.0), and it has been found convenient to retain this throughout. The standard axes in the tangent plane to the sphere at this point are respectively at right angles to and along the projection of the meridian through the standard centre.

§ 5. *Construction of the Standard System of Comparison Stars.*—In the Paris circulars Nos. 8 and 9 the results of the meridian observations of the reference stars made at a number of observatories are given in the form of a table of mean places found by each observatory. As the number of observations at different observatories varied very much it seemed well to weight the results by the square root of the number of observations on which each depends.

It should be noticed that the system of weights adopted is by no means unimportant. I have remarked in the *Observatory* (vol. xxvi. p. 342) that the final places of the reference stars adopted at Bordeaux, Paris, and Cambridge differ systematically from one another, and that in consequence *absolute* places determined by these three observatories would not be homogeneous, and could not properly be used as they stand in a determination of the solar parallax. As, however, I have ventured to contend that it is a mistake to attempt to deduce absolute places of the planet for use in the parallax equations, and shall throughout this paper consider the deduced places of the planet as relative only to my adopted system of stars, it is not necessary to insist further on this point.

Rectangular co-ordinates for the standard centre and axes were calculated from the adopted places of the reference stars for

1900.0, and these will, as usual, be called standard co-ordinates.

The places of the standard comparison stars were obtained from Paris and Cambridge plates. The Paris plates contained a number of the standard stars in the 20′ square; and a set of Cambridge plates was specially measured with all the available reference stars. These measures, referred to many different centres, were all transformed approximately to the standard centre and axes by the method given in § 8.

The six constants of the ordinary linear reduction were determined from the reference stars on each selected Paris and Cambridge plate, and the comparison stars were thus reduced to standard. On collecting the results it appeared that the places deduced from the two series of plates agreed fairly well with one another. The Cambridge x co-ordinates averaged $0''.1$ greater than the corresponding places, which is probably an effect of the nature of magnitude equation due to the fact that the Paris plates were reduced with many more bright reference stars than the Cambridge plates; it has been shown that there is a sensible magnitude equation in the meridian places (F. Cohn, *A. N.* 3952). But when the differences Cambridge minus Paris were classified with respect to magnitude there was little if any trace of relative magnitude equation between the two. It is possible, therefore, that the zero of the adopted places of the standard stars, the simple mean of all the individual results, may be affected by magnitude equation, but the internal smoothness of the system is unaffected by it. The number of places included in each mean averaged 6.5. It was estimated that the probable divergence of any adopted place from a smooth system (not necessarily from its absolute place) would be less than $0''.1$; and it will be shown later that the internal errors of the system are actually a good deal smaller than was estimated (see § 10).

The resulting catalogue of standard places of forty-eight comparison stars has served for the complete reduction to standard of all the plates (with the exception of one series which will be mentioned later).

§ 6. *Choice of Scale Unit and Reduction to Scale.*—The greater part of the measures sent to me were expressed in millimetres on the plate, the remainder in terms of the 5 mm. réseau. As the focal lengths of the telescopes employed varied from nine to twenty feet it was necessary to adopt some standard scale to which everything should be reduced. As proposed in the second paper, I have converted all the measures into a scale whose unit is the one-thousandth part of the focal length of the telescopes

employed respectively in making the photographs. One unit in the fourth place of decimals is then very nearly 0″.02; the probable error of a single measure on the best plates is about three times this quantity, so that my unit is just about the right size to give a suitable degree of accuracy in the computations, without any superfluous figures, if the reductions of the stars are carried out to four places of decimals, and the reductions of the measures of the planet only to five.

The first step in the treatment of all the measures was to reduce them approximately to this standard scale of one-thousandth the radius of projection by multiplication on the arithmometer.

§ 7. *Second Order Terms in the Differential Refraction.*—The next step was to apply to the measures such part of the correction for differential refraction as involves the squares of the co-ordinates on the plate. These corrections rarely amount to more than a few units in the fourth place; but since they consist of the sum of six small terms they are troublesome to compute. To save this labor I have devised a graphical method of determining them, which is described in *Monthly Notices*, lxiii. 138, 1903 Jan. This method has been used throughout, and has been found very convenient.

§ 8. *Transformation to the Standard Centre.*—The next step is to transform the measured co-ordinates to the standard centre.

Let the R. A. and Decl. of the original centre of the plate be A_1, D_1; and of the standard centre be A_2, D_2; and let $A_2 - A_1 = \alpha$

Then if x_1, y_1 be the measured co-ordinates of a star, x_2, y_2 those co-ordinates transformed to the standard centre, it is easy to show that

$$x_2 = [x_1 . \cos\alpha + y_1 . \sin D_1 \sin\alpha - \cos D_1 \sin\alpha]\,/N$$
$$y_2 = [- x_1 . \sin D_2 \sin\alpha + y_1 (\cos D_1 \cos D_2 + \sin D_1 \sin D_2 \cos\alpha) + \sin D_1 \cos D_2 - \cos D_1 \sin D_2 \cos\alpha]/N$$

where the denominator N is equal to

$$x_1 . \cos D_2 \sin\alpha + y_1 (\cos D_1 \sin D_2 - \cos D_2 \sin D_1 \cos\alpha) + \sin D_1 \sin D_2 + \cos D_1 \cos D_2 \cos\alpha$$

A rigorous transformation by these formulæ is exceedingly cumbersome; it is, however, unnecessary. The transformation differs from a linear transformation owing to the presence of the denominator, and consequent introduction of terms of the second order in x_1 and y_1. But when the distance between centres amounts to only a few degrees these terms are small; and when the distance is only a few minutes they are negligible.

Consider the following equations:

$$Mx_2 = (x_1 + By_1 + C)\ (1 - Kx_1 - Ly_1)$$
$$My_2 = (-Bx_1 + y_1 + D)\ (1 - Kx_1 - Ly_1)$$

where $B = \sin D_2 \sin \alpha.$

C and D are approximate mean values of $x_2 - x_1$ and $y_2 - y_1$, obtained by inspection of the measured and standard co-ordinates.

$$K = \cos D_2 \sin \alpha / M.$$
$$L = (\cos D_1 \sin D_2 - \sin D_1 \cos D_2 \cos \alpha)/M$$

and $M = \sin D_1 \sin D_2 + \cos D_1 \cos D_2 \cos \alpha.$

For a range of centering such as I have used M never differs from unity by more than 0.0005. We can neglect it in the calculation of K and L, and need not trouble to multiply x_2 and y_2 by it, since the small change of scale value introduced will be eliminated in the further reductions. The numerators differ slightly from the rigorous expressions, but are sufficiently close to it to give the terms of the second order. If, therefore, we transform by these approximate relations, omitting M, instead of by the exact expressions given before, we introduce the second order terms accurately, but leave outstanding some not very large terms of the first order, which are included in the linear reduction which follows.

When our unit is the one-thousandth of the radius of projection, and $D_2 = 54° 22'$, we have

$$B = \alpha \times 0.000\,236$$
$$K = \alpha \times 0.000\,000\,169$$
$$L = (D_2 - D_1)' \times 0.000\,000\,291$$
$$+ \alpha^2 \times 0.000\,000\,000\,020,$$

where α is $(A_2 - A_1)$ expressed in minutes of arc, and K, L have been adjusted to the unit in which the x's and y's are expressed.

This method of approximate transformation of centres has been used throughout, and has proved very simple and convenient. When the plates are in pairs—that is, two exposures close together on one actual plate—these computations are easily checked by differencing.

§ 9. *Reduction to Standard.*—The six constants of the linear formulæ for reduction to standard were determined for each plate in the usual way by the method proposed by Dyson. When there are many plates with the same group of comparison stars it saves work to invert the process and reduce standard to ob-

served; only the numerical terms are then different from plate to plate. Afterwards the constants thus found must be reversed, and when their values are large the reversal involves a little more than mere change of sign. It is easily shown that if a, b, c, d, e, f are the constants for reduction of standard to observed, and A, B, C, D, E, F the constants for reduction of observed to standard, then

$$\begin{array}{ll} A = -a + a^2 + bd & D = -d + ad + de \\ B = -b + ab + be & E = -e + bd + e^2 \\ C = -c + ac + bf & F = -f + cd + ef \end{array}$$

These expressions are used in a paper by the author in the *Astronomical Journal*, No. 475 (vol. xx. p. 151); but it should be noted that a misprint occurs there of c for e in two places.

All the comparison stars as well as the planet have been reduced to standard, and the residuals formed from the adopted standard places. The condition that the sum of the residuals in each co-ordinate should be zero is a valuable final check on a reduction of which the greater part has already automatically checked itself.

§ 10. *Accuracy of the Adopted Standard System of Comparison Stars.*—The residuals in the reduction of each star, in the sense standard minus observed, may be considered as apparent corrections to the adopted standard places. They have been collected from the Cambridge, Lick, and Paris reduction sheets, and an apparent mean correction formed for each star that had been used more than six times. The mean of all, without regard to sign, was

$$0''.04 \text{ in } x \qquad\qquad 0''.05 \text{ in } y$$

Of course these individual apparent corrections are really corrections relative to the mean of the group of about ten stars used in the reduction of the plate, so that they will average a little less than the corrections relative to the mean of the whole system. But the groups are thoroughly interwoven and overlapped, and the uniform character of the residuals is a sufficient guarantee against any sudden discontinuities in the system, which alone could do serious harm.

Moreover the residuals used in the above discussion are not altogether free from the effects of certain systematic errors which will be discussed later, and whose elimination would have some tendency to reduce discordances. I think that we may conclude that the P.E. of an adopted standard place is at least as small as $\pm\ 0''.04$, and that the effect of errors in the standard places on the resulting places of the planet will be very small.

§ 11. *Examination of the Series of Photographs for Systematic Error.*—If it had been possible for each observatory to secure observations of *Eros* symmetrically disposed with regard to the meridian there would have been comparatively little reason to fear that systematic errors running through a series of photographs would prejudicially affect the value of the solar parallax deduced from them. But it was actually the case that bad weather made large and unsymmetrical gaps in the work of all observatories. Moreover some observatories have a large preponderance of evening observations in the days about opposition, and all have of necessity a great excess of post-meridian observations throughout the period some weeks after opposition, when the planet was nearest and its parallax greatest. This inevitable dissymmetry gives every opportunity to systematic errors to exert a baneful effect, and it seems to me not possible to accept as axiomatic the statement, which has been made more than once, that they may be trusted to eliminate one another completely in the combination of a large series of observations. On the contrary, two of the series of photographs which we shall have to discuss contain systematic errors so large that they would ruin any determination of the solar parallax into which they were introduced. The errors can, however, be detected by an examination of the residuals in the comparison star reductions. Our next step will be to show that a critical examination of the residuals in each series of plates must be made an essential part of any discussion of the solar parallax from photographs.

It will be convenient to summarize the kinds of error to which attention has at various times been directed.

Errors of Measurement.—All experience goes to show that these are relatively unimportant. The Cambridge machine has no sensible errors of scale or screw, and it will be shown later that the réseau is nearly perfect. The evidence for freedom from error of other machines whose results enter here is not complete, but it may be assumed that there are no large errors. There seems good reason to believe that personality in measurement is very nearly eliminated by reversal of the plate, which has been done in all series except one.

Real Errors of the Image.—A large part of the error in a measured co-ordinate is due to real error in the position of the image. Evidence is accumulating that a set of images close together may be affected by a quite large common error, which is probably local distortion of the gelatine film within the réseau

square. When no réseau is used this error may of course be much greater.

Constant Optical Distortion of the field may be expected in reflector photographs, but not otherwise. There seems good reason to suppose *a priori* that it should be symmetrical about the centre of the field, but it will evidently depend very much upon the brightness of the stars.

Hour-angle error.—Under this name Kapteyn conveniently includes the effect of atmospheric dispersion, and also optical distortions and tilt of plate, varying with the hour angle, due to flexure of objectives, mirrors, and mountings.

Magnitude Equation and Guiding Error.—If the driving is not perfect, but there is a tendency to accumulate error in one direction until it is corrected by hand or automatic control, the brighter stars may be displaced relatively to the faint, and show a kind of magnitude equation varying from plate to plate, but on any one plate depending on the magnitude of the star alone. This is probably one of the most important and subtle errors of the photographic method. It is distinguished from other kinds of magnitude equation, due to an imperfectly symmetrical diffraction pattern of the image, or to personality of measurement, by the fact that its appearance will be capricious.

We shall have occasion to deal with most of these sources of error in the discussion that follows.

A. *The Lick Plates.*—The Lick plates were taken with the Crossley reflector of 36-inch aperture and 17.6 feet focal length, with short exposures averaging 15^s. They were measured on the Repsold machine at Columbia University Observatory, N. Y. Upon reduction to standard the comparison stars on many of the plates had unduly large residuals, amounting in some cases to a second of arc. There was plenty of evidence from other sources that the standard places were of a high order of accuracy, and it became clear that the error was to be found in the plates or the measures. It was chiefly in the x co-ordinates, appearing in this way. The x residuals, in the sense adopted standard minus reduced measure, were positive for stars near the middle region in x, and negative for stars towards both sides, the sum of the residuals being necessarily zero. This arrangement of signs indicated an apparent bodily displacement of the central images relative to the outer, and there was consequently every reason to fear that the positions of the planet deduced from the plates might be systematically wrong. The effect was not constant; on a few plates it seemed to be absent, and in one

or two cases changed sign. It had no apparent relation to the hour angle; was almost exactly the same for a pair of exposures on the same plate, but varied capriciously from plate to plate.

In general character it resembled the effect of a tilt of the plate relative to the optical axis, such as might be caused by an error in squaring on the plate, or by defective collimation of the mirrors. But it needed only a small computation of the amount of tilt required to explain the magnitude of the error, to show that this explanation was grotesque: a tilt of several degrees is entirely out of the question.

The asymmetry of the error with respect to the centre seemed to make it improbable that it was due to optical distortion.

In order to elucidate this perplexing question the Director of the Columbia University Observatory very kindly had measures made of a large number of stars on certain overlapping plates, and the reduction of these confirmed the reality of the error without throwing any light on its cause. I then asked Professor Campbell to be so good as to let me examine some of the plates at Cambridge, and he very kindly sent me three of them. Inspection showed that there was no possibility of a large tilt of the plate; the optical centre was strongly marked by the perfection of the images around it and their regular degradation as they departed from it. It appeared to me, however, that many stars had been measured which I should myself have judged unfit for measurement on account of the familiar umbrella-shaped character of the images, so I decided to try rejecting all the measures of stars more than 20 mm. or 13′ from the centre—that is to say, all stars whose discs were not sensibly round. The effect of doing so was remarkable. When a new solution was made with the stars that were left the residuals were quite small, and the resulting place of the planet was very much altered; and when the outer rejected stars were reduced to standard with the constants derived from the inner stars they gave residuals up to 1″.5.

It is clear that the error was due to the use of stars too far from the centre, and that it is unsafe to measure the Crossley plates where the star discs are not sensibly round. But it remains a mystery why the error should take the shape it does. The images are distorted quite symmetrically with respect to the centre, and there seems no reason why the observer should make an error of measurement always more or less in the same direction on images oppositely distorted. I have tried to go further into this matter, and to discover something more definite about

the law of the error, but have failed. This is, perhaps, not surprising when one considers that the shape of the distorted image depends very much on the magnitude of the star as well as on its position. It is unlikely that one will ever be able in such a complicated case to devise a system of corrections applicable to measures of distorted discs, and the safe course will be to confine measurements of these plates to a field of about 12′ radius, within which the images are small and beautifully defined.

The places of *Eros* to be used in the present reductions depend entirely on these central stars.

B. *Algiers Plates.*—A very puzzling error exists in the Algiers plates, which are taken with the standard Astrographic Refractor. I had hoped to be able to use the Algiers measures in forming the system of standard stars, for many of those stars were to be found in the 20′ square about the planet. But when they were reduced to standard with the aid of the reference stars in the usual way they were systematically discordant from the results of the Cambridge and Paris plates, and could not be used.

At first sight the error looked like a magnitude equation making the x's of faint stars too large; but I am now convinced that magnitude equation is not the chief error. It would be hard to go into details without taking up too much space; the question is much complicated by the fact that the stars measured near the center of the plate are mostly faint, and the stars further out most of them brighter; they give respectively negative and positive residuals. To examine this question properly, it would be necessary to measure both bright and faint stars distributed uniformly over the plate. But I have found as a rule that a bright star among faint ones near the centre gives a negative residual very much like theirs, while a faint reference star far out gives a positive residual as large as that for neighboring brighter stars. Further, if very few stars in the center of the field have been measured at all, the residuals immediately become small, and there is no marked magnitude equation between bright and faint outer stars. The conclusion seems to be that the central stars are displaced upon the plate, not because they are faint, but because they are central; and it was entirely consistent with this to find that Algiers places of the planet differed systematically from the Paris and Cambridge places by quantities of the order of half a second of arc.

This is very remarkable. One is accustomed to expect certain difficulties with a reflector; but it is disquieting to find that a standard astrographic refractor, when devoted to solar

parallax work after long use on the astrographic chart and catalogue, can give results which are wrong by amounts quite serious when judged from the standard of the catalogue, and hopeless as they stand for parallax work. It is not easy to imagine what may be the cause. We cannot suppose that the plates were tilted enough to explain it, and we have not material enough to find a general expression of the second degree to represent it.

It is hard to decide what to do in a case like this. If the error is like the error in the Lick plates, and develops suddenly as one gets away from the centre, it is probably safe to rely on the central stars to give a good reduction. This appears to be the case. Having decided to reject altogether the stars outside the 20′ square, I chose some additional standard stars, and got their places as before, measured them on the Algiers plates, and so had always at least six stars for the reduction, except in a few cases where scarcely any central stars appeared on the plates; these were rejected.

The new places of the plant differed from the old by amounts up to 0″.65 and averaging 0″.48. They seemed to fit the ephemeris very well. But it must be admitted that this is our only ground for assuming that the error for whose existence we can assign no reasonable cause has been altogether eliminated.

C. *Cambridge Plates. Search for Réseau Errors.*—On the Cambridge plates the planet is not always referred to precisely the same réseau line, whose error, if any, might appear to give a uniform correction to the place; nor is it referred to so many different lines that accidental errors might be expected to go out in the long run. The réseau must, therefore, be examined. Several published investigations of Gautier réseaux show that the errors of the réseaux themselves are very small, of the order of the division errors in the best divided scales. But it has recently been shown by Ludendorf (*A. N.* 3746) and Bohlin (*Astr. Iakktagelser*, Stockholm, Bd. 6, No. 5) that a réseau perfect in itself may produce imperfect copies through what is known as projection error. It seems that something—probably the fine cut in the glass made by the diamond point that cuts away the silver—may deviate the light just as it passes through the réseau, and produce errors in the copv much larger than in the original. If we determine the errors of the original we must also determine the projection errors, and both are difficult and troublesome matters. We may, on the other hand, achieve our end, which is to find the errors of the photographic copy (apart from

gelatine distortion), by examining plates impressed with a réseau to a number sufficiently large to eliminate the gelatine distortion, provided that this may be treated as accidental, and vanishing in the mean of a large number of plates. The supposition is most likely correct for the central portions, and incorrect for the edges of the plate; it will serve our present purpose.

I am indebted to Mr. Russell for the use of a strip of photographed réseau, of which he has determined the errors, so that it can be used as a standard scale. This was superposed on several plates, parallel to the X axis, so as to almost coincide with the réseau lines at the points from which the x co-ordinates of the planet are measured. The distances between eight or ten réseau lines on these plates and adjacent lines of the standard scale were measured, the corrections for errors of the scale were applied, and the resulting apparent errors of the photographed réseau in sixteen strips altogether were plotted. The results are briefly as follows:

The apparent errors of successive lines deviate from a smooth and nearly straight line by quantities averaging about 0.001 mm., equivalent to $0''.035$ on my plates; a considerable part of this deviation must be accidental error of measurement. The errors of two points of a line not more than 1 mm. apart are frequently of opposite sign—that is, the line images are a little rough. When means are taken the deviations of the apparent mean errors from uniformity are almost within the limits of probable accidental error. The conclusion is that there is practically no evidence of sensible error in the photographed copies of the réseau, apart from the general smooth distortions of the gelatine film which the use of the réseau eliminates. In one case only did an error amount to 0.005 mm., and at that point the réseau line was obviously defective; the defect had been noted when the plate was measured, and special precautions taken to avoid it.

Search for Hour Angle Error.—It is clear that errors of this category can produce no resulting error in the place of the planet unless they are differential, varying from star to star on the plate. If they are due to dispersion they will bear a definite relation to the projected position of the zenith on the plate. If they are due to variable distortion they will probably at least change continuously with the hour angle. In looking for them I plotted the apparent correction to the adopted place of each comparison star deduced from thirteen groups of four exposures each; and alongside them the relative positions of the projected zenith.

There was no relation to the zenith; nor was there continuity of any kind in the group displacements. I conclude that there is no sign of dispersion or of any differential distortion in the stars on the Cambridge plates. That does not prove that there is no dispersion effect on the planet, but it renders it more unlikely, since there is some experimental evidence to show that the effective wave-length of the planet's light is in no way abnormal (Prosper Henry, *Paris Circular*, No. 8, p. 41).

Guiding Error.—In searching for guiding error one naturally looks for large residuals for the few bright stars, balanced by smaller residuals of opposite sign for the more numerous faint stars. It must, however, be borne in mind that an uneven distribution of the bright stars may to a large extent mask this effect. If we have two or three bright stars at one edge of the group, and no accompanying faint stars, the linear reduction may strain the fit to suit these bright stars at the edge, and leave them with small residuals. The existence of large residuals for certain bright stars, especially if near the centre, is therefore an indication of guiding error which is not necessarily contradicted by the fact that certain other bright stars have not large residuals of the same sign.

On examinations of the residuals for the Cambridge plates I was struck with the fact that the average residual of two bright central stars was large on twelve consecutive plates (1900 November 10), while the residuals for two bright stars at the edge of the group were small. This looked like a case of guiding error, and I was fortunately able to make a more than usually conclusive test. My earlier experimental reduction of this plate depended on faint stars. A comparison of the numerical terms in the equations of condition of this first reduction with the corresponding terms in the present solution ought to show, perhaps, a steadily increasing difference, but no irregularities. This was so, except for the twelve exposures under suspicion, which showed marked divergences of about $0''.2$, and strengthened the idea that the bright stars were in error and spoiling the reduction. I therefore rejected these four stars and used four fainter, making a new solution which gave decidedly different values of the constants, and altered the place of the planet by about $0''.1$ on an average.

No other plates show signs of guiding error comparable with this found on the bad set of twelve consecutive plates, which may perhaps be attributed to some temporary derangement of the automatic control. But the possibility of so large an error

affecting a series of exposures with large parallax factors of the same sign is one that must be reckoned with, and seems to me a most powerful argument for the necessity of examining the residuals of all the comparison stars on every plate.

D. *San Fernando Plates.*—The result of the reduction of the San Fernando plates is disappointing. Admiral Viniegra very kindly had measured for me the places of all my selected comparison stars, in order to give additional material for the formation of my standard system; but when the reductions were made the results differed so largely and irregularly from the accordant results of Paris and Cambridge that it seemed unwise to use them in the formation of the standard system. On inquiry I learned that the plates had been measured in only one orientation. This fact compels me, very regretfully, to exclude the San Fernando results from my solution.

E. *Northfield Plates.*—A good many of the Northfield plates were taken on a plan which, one may venture to say, is certainly unsatisfactory. The guiding star was placed successively on the four corners of a square reticle, and then once more on the first corner. The motion of *Eros* in the interval was sufficient to clear the images of the planet, but the stars in the first corner exposures are superposed and measured as one set. Apart from the fact that the fit of the two sets of star images cannot be perfect, owing to changes in the differential refraction, orientation due to maladjustment of polar axis, etc., there are grave reasons for fearing guiding error when two exposures are superposed with an accuracy limited by the accuracy of pointing with a not very powerful guiding telescope. I think that there can be no doubt that the comparative roughness of the Northfield results is partly due to this procedure. An examination of the comparison star residuals does not, however, show any signs of systematic error on the plates.

F. *Minneapolis Plates.*—An examination of the residuals in the reduction of the comparison stars to standard showed an error which is probably due to some kind of optical distortion. The measurers' notes contain references to elongated and winged images, and it is clear from the Lick results that these must be treated with caution. I should have tried to treat these plates in the same way that the Lick plates were treated had it not been for the fact that on many Minneapolis plates the images of the planet are far from the centre of the plate, and the group of comparison stars is in consequence very unsymmetrically placed upon it. As an experiment I have made new solutions after re-

jecting the outer stars of the originally selected groups, and have obtained new places of the planet differing systematically from the old. But, owing to the want of symmetry, there does not seem to be any guarantee that these new places are clear of error; and the danger of using them is aggravated by the fact that the parallax factors for the Minneapolis plates are nearly all of one sign. On taking all these things into account I was very reluctantly compelled to decide that it would be safer to leave out the Minneapolis results from my solution.

The Minneapolis plates also suffer from the fact that a good many of the exposures on the stars are multiple, made at intervals great enough to allow the images of the moving planet to clear one another. The roughness of the accordance between the resulting places of the planet and the ephemeris confirms the impression derived from the Northfield plates that this is a method of procedure which should not be employed again.

G. *Oxford Plates.*—On one of the Oxford plates there is a clear case of guiding error running almost uniformly through half a dozen exposures. It has been treated in the same way as the like Cambridge case, by rejecting the bright stars and solving afresh.

H. *Paris Plates.*—No case of abnormality or suspicion of systematic error has arisen in the examination of the Paris star residuals.

(TO BE CONCLUDED.)

A THREE-INCH TELESCOPE FOR THE HIGH SCHOOL.

WM. W. PAYNE.

Since the question of teaching the elements of Astronomy in the public high school has been under discussion in this magazine, we have received a number of letters from persons in different parts of the United States, urging us to continue the work so favorably begun, and to bring it definitely to the attention of superintendents and science teachers in the high school so that they may clearly understand the advantages to be derived from introducing elementary astronomy into the high school course, and may have knowledge of some of the more modern ways of giving instruction in this branch of study, by what may be given in this publication, and in other ways that may be accessible to those in want of such information.

It is gratifying and encouraging to know that some of the superintendents of the high schools in Minnesota have been con-

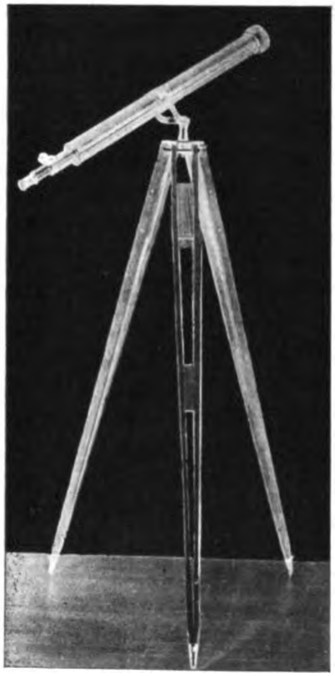
sidering this matter very thoroughly, and have written about it very pointedly and very intelligently. Professors in some academies, colleges and universities have done the same. The positions taken by these teachers and school officers have been so strong and so urgent, that it has seemed wise to us to try and help so worthy a cause more in the future than we have been able to do in the past, especially since we know of this general interest and that persons so interested stand in the front rank of educational work at the present time.

In looking into this matter carefully, it has seemed to us that the first thing to do was to secure a good telescope that would be especially adapted to high school uses, and still be within the reach of most high schools so far as the price of the instrument is concerned. There is a very delicate and important point in the plan to be unfolded. The optical work must be perfect, the mounting should be strong and light and convenient in form for ready and safe handling. The clear aperture of the object glass should be at least three inches in diameter and there should be three direct eye-pieces varying in power from about 25 diameters to 150. The plan of the mounting and the work in detail should be the best that responsible and reputable makers can devise and execute. After discussing this problem with some of the best practical opticians and makers of the mountings of telescopes, with the wants of this class of schools in mind, we will give, somewhat in detail, the results of these conferences.

In order to test the opinions of some of the well-known makers of telescopes, and to compare their claims carefully with our own tests, we asked that a sample telescope of this kind be made for us especially, that we might examine it thoroughly so that we might inform all persons interested in such an instrument, about its workmanship, and just what it would show in the study of the heavenly bodies. We asked that the object glass be three inches, clear aperture, in a brass tube, finely laquered, and mounted in alt-azimuth fashion, on a tripod whose legs are about six feet long. Considerable more of detail was considered regarding the quality and finish of such an instrument, its cost, and its care that need not be specified at this time, but which will be spoken of later in another connection.

In a short time after the above order was given, the telescope was completed and shipped to Northfield, but it came during the two months of absence in the Rocky Mountains, so that an examination of it was necessarily deferred until last month after our return from the West.

That our readers may see how the telescope looks, I asked Dr. Wilson to take a photograph of it, and the accompanying cut has been made from the photograph secured by him for this purpose.



Our readers will please notice that the tripod is made long so that it may stand high when direct eye-pieces are used, for the convenience of the observer. Most telescopes of this size in general use have such low and light mountings, that much of the advantage of using them is lost, because of the awkward, uncomfortable and unsteady position that the observer must be in, much of the time, to use them. Very often, too, small telescopes of commercial make have such small and light mountings as to make them very unsteady if they are in use when wind is blowing even lightly. A mounting intended to be used on a table is in no way desirable. It will be a great mistake to try to use a three-inch instrument in that way. While the mounting of this sample telescope looks high and light for so small an instrument, it is found to be very steady because the legs of the tripod are made of oak, in divided form, and securely stayed with two blocks of oak, for each, for strength and lightness and to avoid wind tremors as much as possible in open air use. Though not

shown in this cut, the instrument is provided with a plain box for the telescope and the three direct eye-pieces, so that the optical parts when not in use may be kept from dust and needless handling. How to care for the object-glass and eye-pieces of a telescope will be spoken of later. When a new telescope is to be used for the first time, or by one not accustomed to such work, especial care should be exercised that none of the parts be injured in setting it up and in making trial of it.

Usually makers are careful in packing instruments which are to be shipped to any considerable distance, and the chances are very few that they will be harmed at all in transit to the purchasers.

When the new telescope is ready for use an inexperienced observer can very soon tell for himself if the telescope works well. Try an easy object like the Moon, Jupiter, Saturn or any one of the bright stars. Any one can readily tell if the images are sharp and distinct in the central part of the field. By moving the eye-piece in or out from the true focal plane a little attention to the images so formed will give information how well the maker has succeeded in finishing the glasses in the objective in regard to proper curvature and color-correction. We give below some illustrations suggested by E. Walter Maunder of England, in *Knowledge Diary and Hand-book*, for 1904, indicating fairly well how object-glasses form images, if perfect or imperfect, and what the defects are in either case. The figures from 2 to 7 show the appearances of the image of a bright star in good eye-pieces, when thrown out of focus. Figures 2 to 6 show the appearances seen under different conditions of defect or faulty adjustment of the object-glass.* Figure 7, those seen when a perfect objective is in complete

FIG. 2.—Appearances observed when objective is out of quare.

a. b. c. d.

FIG. 3.—Diagrams showing effects due to (a) flexure; (b and c) strain in cell; (d) veins on objective.

adjustment, showing the ring system belonging to the spurious image of a star so-called. Inexperienced observers must not

FIG. 4.—Appearances due to spherical aberration.

expect to see actual star images as strongly marked in ring effect as the last figure shows. The seeing must be very good

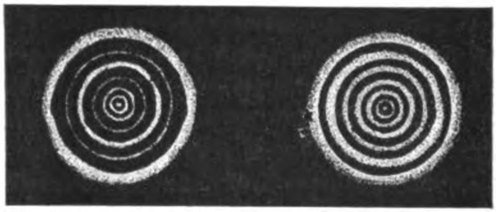
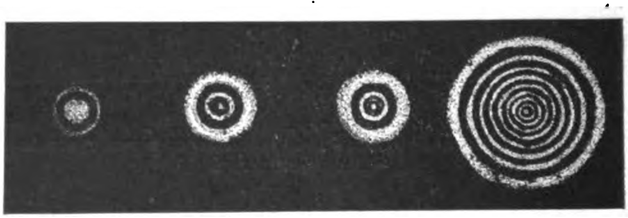


FIG. 5.—Appearances due to zonal aberration.

and the telescope quite perfect to get the diffraction rings plainly. The other figures produced from the conditions named if such

FIG. 6.—Elliptic rings produced by astigmatism.

exist will be easily seen and readily noticed by one having little experience, if the attention is once called to it.



a. b. c. d.

FIG. 7.—Diagram showing spurious disc and refraction rings seen with a perfect objective, (a) in focus; (b) a little within the focus; (c) a little ontside the focus; (d) far from the focus.

September 21, about noon, the new telescope was turned on the Sun, and the image thrown out of focus and projected on a piece of white card-board, using each of the three powers 25, 50, 150. The seeing was about six on a scale of ten; sky was milky and the wind was blowing from the east at a rate of about ten miles per hour. The image of the Sun was clearly defined, the limb showing the brown border, for about one-fourth of the radius, due to absorption. The even and gradual fading out of this darkening of the limb, as the eye passed inward, toward the center made a fine picture of symmetry that was very satisfactory. One small spot was in view, but it was too small for detailed observation. The seeing was not good enough to show the granular structure, or the faculæ, if prominent markings of this kind were in view at the time.

On Sept. 20, 8^h, the Moon was observed with all the powers. The seeing at that time was about eight on a scale of ten. In looking at the limb of the Moon for color, but a very thin thread of it could be seen anywhere in the field when the focus at the center of the gibbous Moon was at its best. In this instance the color correction of the lenses in the light of the images seems to be almost entirely free from any noticeable errors. Our readers, doubtless, already know that no telescope maker has yet found a way to construct a refracting instrument whose images should be absolutely free from color. Physicists believe that the difficulty is theoretical, and so impossible of removal until some new and better method has been discovered. Although the Moon is an easy object for a good three-inch telescope, a careful examination of the fine details of the surface will give ample opportunity for testing the definition. We looked at the craters Tycho, Copernicus and Gassendi. The terraces of the inner and outer sides of the walls of these great craters were well seen, the peaks surmounting the walls and the shadows on the floors of the craters were also seen, this being a harder test than the former one. We then tried a study of the floor of Gassendi. We could see that it was uneven and that its central mountain had three peaks, but the seeing was not good enough to show the many rills and craterlets, that possibly might be observed under better conditions, judging from what else was seen, not much more difficult.

Jupiter, which is not a very difficult object for a three-inch telescope, was next observed. Its moons were all in view, and its more prominent belts were easily seen. The detail of the great southern belt was considerable, and, in power 150, gave a very in-

teresting view. The unequal polar and equatorial diameters of the planet were readily detected by the eye, without the aid of measures of any kind.

The planet Saturn was next in view. It was near the meridian and about 5° south-west of the Moon. The ball and ring were fully separated, the middle of the ring is brighter than its inner or outer parts, as it should be. The inner edge shows the strong darkening that belongs to the portion known as the crape ring, but the full width of the part of the ring could not be seen; we did not expect that, for such observation was too hard for a three-inch aperture in such seeing as that evening afforded. We also saw the belts on the disc of the planet, and glimpsed the Cassini division of the rings at the right ansæ. The view of Saturn was unexpectedly satisfactory.

The view of the bright Vega, (α Lyræ) was taken to see how the star images would look when the eye-pieces were out of focus. That would help us to understand if there were any zones in the objective that were poor in fignre or bad in centering by lack of care on the part of the optician. It is a pleasure to say that no such defects were found, but that the images were like those in Fig. 7 showing the ring system as plainly and as well as could be expected from the seeing at the time. The view of the double star Mizar in Ursa Major was a fine one with the power of 150.

The Mizar components were clean and sharp, and their star colors were perfectly shown, as white and emerald, which is according to the best authority we know of in the star-color work.

The night was not good enough to put the new telescope to the severest tests that it should bear theoretically, and we have not yet been able to do that before this writing which must be completed now for our forthcoming issue. We have only fairly begun to show what a fine three-inch can do, and this work will be continued until those interested in the right kind of telescope for the high school shall become acquainted with knowledge of these things easily within their reach.

It should be stated that the publisher of this magazine has no financial interest in this telescope except that he is the owner of it, having paid $90.00 for it, exactly what any one else could buy it for. He personally knows the makers as well as many others in the United States, some of whom can make just as good a telescope as this one undoubtedly, if they were asked to fill such an order.

The whole object of the writer is to bring to the attention of high school authorities what seems to us, one of the best

branches of study that could be in a high school course, with suggestions how to pursue it most effectively.

PROFESSOR WINCHELL'S NOTES ON A VERY BRILLIANT METEORITE.*

The brilliant meteoric phenomenon which passed from west to the east early last Wednesday morning, July 26, and which was witnessed by a few people in different parts of the state was one of the most brilliant displays of light for a good many years. The young ladies and gentlemen who were guests at Idlewild cottage, had the pleasure of looking upon this awe-inspiring turning of night into day. The young people were returning from New Paynesville, Minnesota, at about 12:30 Wednesday morning when the brilliant meteor passed over the heavens. It lasted a quarter of a minute and during that time the opposite shores of the lake could be seen almost as plain as in broad day. The awful light proved conducive to a good many inward shudders. —Litchfield *Independent.*

Speaking of the search which he himself made, Professor Winchell says:

I started out at once on hearing that the meteorite had been found near Kenyon, although there were statements in the newspaper accounts that were palpably erroneous. Those errors I thought might be due to hurried statements by the reporter augmented by a lively imagination. What was my chagrin on finding that the reporter had made up the whole account from imagination—excepting only that it was true that on the night stated a meteoric disturbance and a loud noise were witnessed in Goodhue county, and that the meteor's streak was seen to the north from Kenyon.

With that as a basis I started across the country northward, calling at the farm where it had been reported that the meteorite

* On the morning of July 26, 1904, a very brilliant, detonating meteorite made its appearance in southern Minnesota. In the vicinity of its path its wonderful display attracted considerable attention, from the few who were fortunate enough to see it, and from the many later who were aware of the near approach of such a dangerous, celestial visitor. Those in charge of this publication were in Montana when this interesting phenomenon occurred, so that no personal attention could be given to it. The management, however, is fortunate in having the aid of Professor N. H. Winchell of Minneapolis, in securing the following facts about this new meteorite. Professor Winchell's great interest in the study of meteorites is well known to scholars in Geology and Astronomy.

had "burned the oak trees." Only stating that there is not an oak tree on that farm, and has not been within the knowledge of the old pioneer who owns it, I would say that I made frequent inquiries along the road toward Holden and Dennison but could get no positive statements until I reached Dennison. This I attributed to the fact that the visitor came in the dead of night and was not heard. At Dennison I was directed to Mr. Kelly, a druggist of Northfield, but found that he knew nothing of the matter. He suggested that Mr. D. A. Kelley, who lives in the south-eastern suburbs of Northfield might be the man meant by the people at Dennison. Arriving at Mr. D. A. Kelley's house I found, agreeably to my surprise, that the ladies, who had happened to be out late that evening, had retained a vivid recollection of the event. Their description was consistent and evidently accurate. There was a stream of light, a rumbling noise and lastly an explosion. It was toward the north-east from them, and seemed not to be far away, but moving to the eastward from them.

The substance of the rest of my trip and search is in the Minneapolis *Journal* extract given below.

"At George Lyman's, about three miles east of Northfield, on the road to Dennison, the description given by Mrs. Lyman indicated that the meteorite must have fallen not far from his farm, perhaps somewhat to the north-east. There was a flash and a terrific explosion, loud as a cannon, but "not like a cannon." The whole family were startled from a sound sleep and rushed from their beds to learn whether the house or the barn had been struck by lightning, but it was at once apparent that no thunder could have made the noise, as the sky was clear and the moon was bright.

Although inquiry was made of several others no definite information could be obtained. It was in the dead of night. If a farmer had heard it or had seen the flash he would probably have turned over in bed, only muttering that another thunder shower had risen to wet his already soaked grain fields.

Judging from all the data, I am convinced therefore that the stone fell inside the triangle formed by lines drawn between Lyman's farm, Dennison and Randolph, and probably not more than two miles from Lyman's. The probability is that it is toward Randolph from Lyman's rather than toward Dennison. The chances are good for finding it. At present the country is covered by standing grain. Soon the fields will be everywhere cut by the reaper. If the farmers will be on the lookout it can hardly escape such a reaping and raking.

In falling the stone must have made some impression on the grain and soil. The former is destroyed by being beaten into the ground over a space say of a square yard, and the latter may show a hole in the ground where the stone struck. The stone may have entered the soil a few inches and be invisible, or it may have bounded out and may lie a few feet from the point of first impact. It was not hot enough to burn anything. When the Winnebago meteorite fell it struck a dry turf on which was some long, dead grass. The stone went into the turf and did not burn the dry grass, as it was found adhering to the stone afterwards, when it was taken out. Another small piece fell on a straw stack and did not fire the straw.

The popular notion that these stones are hot is erroneous. The heat is entirely superficial and vanishes at once. It is caused by the condensation and friction of the air along the path of the stone through the atmosphere, but it does not last long enough to heat the stone within. It is probably this friction also which causes the stone to break, as they usually do, and to cause the loud reports heard near the point of striking the earth. As to the appearance of the stone, it is black and smooth, or brown-black. It is gray within, but owing to the fusion of the outside a thin crust is formed all over it which is nearly black. In case the stone broke into two or more pieces, the surfaces of fracture will show a thin crust, or, perhaps, will be only slightly colored depending on the distance the pieces traveled in the atmosphere after the explosion.

The region is one of original prairie, and has few stones on the upland. Hence the farmer's attention would be attracted at once by the appearance of such a stranger on his field. I would especially urge the drivers of the teams that haul the reapers to be on the watch for any appearance of unusual downthrow of the standing grain, and also to scan carefully any small new hole in the soil which has the appearance of having been made by the descent of this meteorite.

In case the meteorite is found, or in case any one finds a stone that he thinks may be the meteorite, I shall be glad to give any information I can. It is very much to be desired that this third celestial visitor be properly received and cared for.

Planet Notes for November.

H. C. WILSON.

Mercury will be at superior conjunction on the morning of Oct. 31 and will not be easily visible to the naked eye during November. The planet will be at aphelion Nov. 13.

One of our readers has been troubled because he found it difficult to see Mercury at the time of the greatest elongation in August. This was because at that time Mercury was near its greatest distance from the Sun. The orbit of Mercury is quite eccentric so that when the planet is at aphelion it is nearly one and a half times as far from the Sun as it is at aphelion. Since the light received from any source varies inversely with the square of the distance, it follows that Mercury receives less than half as much light from the Sun when at aphelion as when at perihelion.

The brightness of Mercury as seen from the Earth depends upon several variable factors, the more important of which are the angle of elongation from

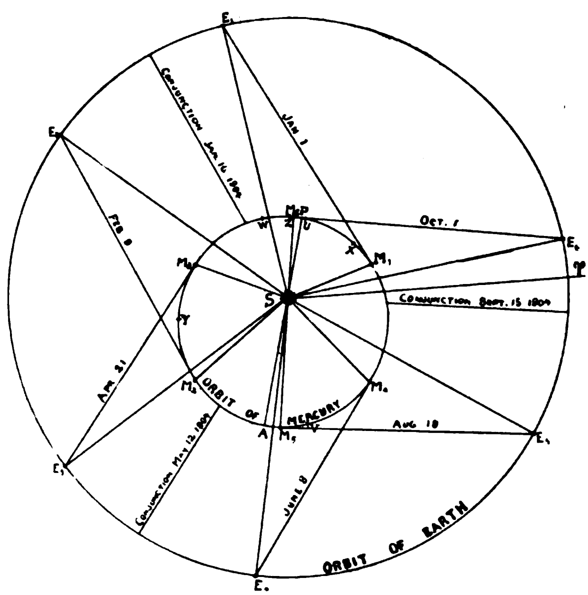
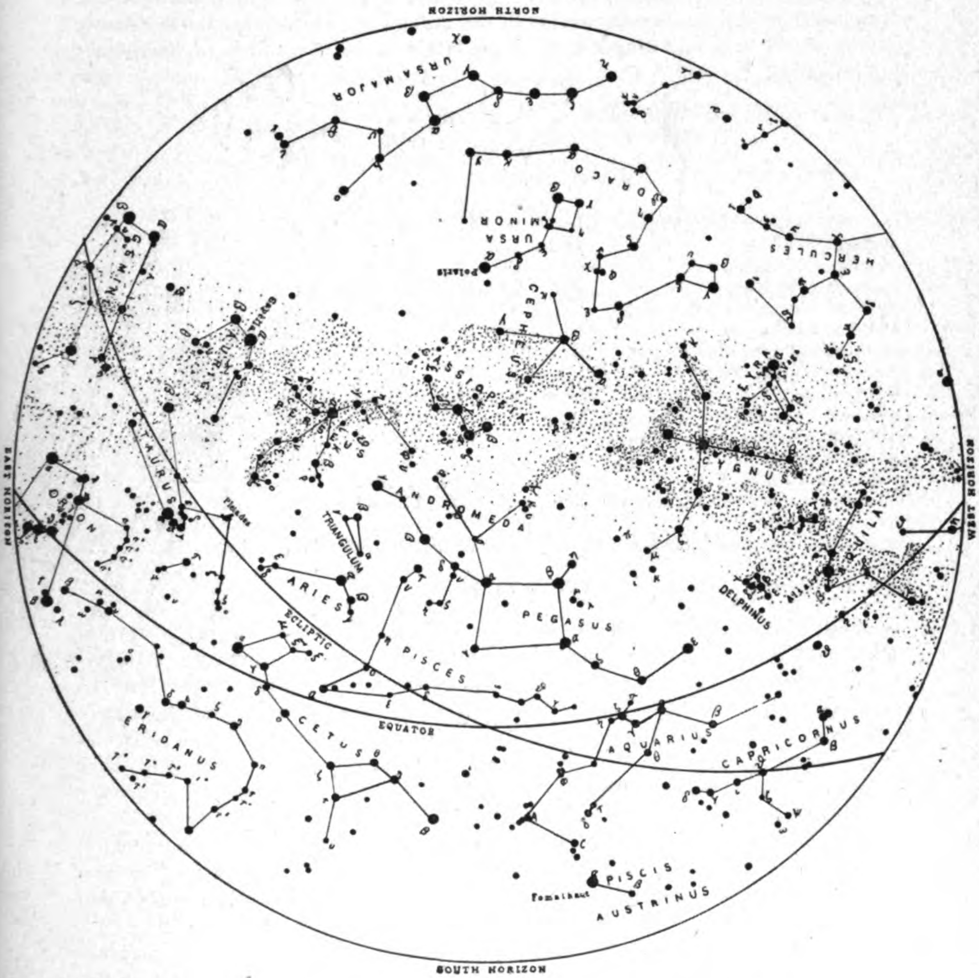


Diagram Showing Positions of Mercury at Greatest Elongation During 1904.

the Sun, the distance from the Sun, the phase of the planet, and its distance from the Earth. The resultant of all these factors causes the time of maximum brilliancy of Mercury to vary very greatly with reference to the time of conjunction or of greatest elongation. I have tried to place before the eye of the reader, in the accompanying diagram, the relations of these four factors at the different greatest elongations of the planet during this year. The angle at E in each of the six positions of the Earth is the angle of greatest elongation from

the Sun, and the visibility of the planet depends very much upon this. It is usually visible for only a week or two about the time of greatest elongation, because it is then most free from the glare of the Sun and may be seen longer after sunset or before sunrise. The lines *M S* indicate the relative distances of the planet from the Sun and *E M* those from the Earth. The angle between these lines at *M* in each case will indicate the phase of the planet, the phase being



THE CONSTELLATIONS AT 9 P. M. NOVEMBER 1, 1904.

gibbous when the angle is less than a right angle and crescent when the angle is greater than a right angle. Thus on Jan. 1 the phase was gibbous, 0.59 of the illuminated hemisphere being visible, while on June 8 it was crescent, only 0.37 of the illuminated hemisphere being turned toward the Earth.

In the following table I have put down the numerical values of the several data, taking them from the *American Ephemeris* for 1904. It is possible that

the last figure may be in error by one, since the interpolation was roughly done. In this table E represents the angle of elongation, r the distance of the planet from the Sun in units of the Earth's mean distance, ρ the distance of the planet from the Earth in the same unit, k the ratio of the area of the illuminated portion of the apparent disk to the area of the entire apparent disk regarded as circular, and L the brilliancy of the disk. The unit of L is the amount of light received by an eye from a circular disk with the same reflecting power as the planet, subtending an angular radius of one second of arc, situated at distance unity from the Sun, and illuminated by the latter as the mean disk of the planet is illuminated.

TABLE SHOWING VARIATION IN BRIGHTNESS OF MERCURY AT GREATEST ELONGATIONS IN 1904.

Aspect of Planet.	Washington M. T. 1904	h	E °	′	r	ρ	k	L
Greatest eastern elongation	Jan. 0	13	19	30	0.33	0.99	0.59	60
Greatest brilliancy	Jan. 2	..	..	..	..	..	..	60
Inferior conjunction	Jan. 16	19	..	..	..	..	..	..
Greatest brilliancy	Feb. 1	..	..	..	..	..	..	41
Greatest western elongation	Feb. 9	16	25	52	0.44	0.99	0.50	40
Greatest brilliancy	Apr. 9	..	..	..	..	..	..	70
Greatest eastern elongation	Apr. 21	4	20	12	0.36	0.86	0.42	45
Superior conjunction	May 12	18	..	..	..	..	..	..
Greatest western elongation	June 8	4	23	46	0.42	0.82	0.37	35
Greatest brilliancy	July 4	..	..	..	..	..	..	68
Greatest eastern elongation	Aug. 19	12	27	24	0.47	0.90	0.52	32
Greatest brilliancy	Aug. 24	..	..	..	..	..	..	32
Inferior conjunction	Sept. 15	9	..	..	..	..	..	..
Greatest western elongation	Oct. 1	3	17	54	0.31	0.99	0.51	65
Greatest brilliancy	Oct. 5	..	..	..	..	..	..	66
Greatest eastern elongation	Dec. 13	16	20	30	0.35	1.00	0.62	54
Greatest brilliancy	Dec. 16	..	..	..	..	..	..	57
Inferior conjunction	Dec. 30	22	..	..	..	..	..	..

From this table it will be seen that during this year the brightness of Mercury at greatest eastern elongation ranged from sixty in January to thirty-two in August, and at greatest western elongation from thirty-five in June to sixty-five in October. Also it will appear that the time of maximum brilliancy sometimes precedes and sometimes follows either greatest eastern or greatest western elongation. In January the greatest brilliancy occurred very soon after greatest eastern elongation the planet being at X in the diagram. In February it preceded greatest western elongation by eight days, the planet being at Y. In April on the other hand greatest brilliancy preceded greatest eastern elongation by twelve days, when the planet was at Z, while it followed greatest western elongation in June by nearly a month and in the mean time the planet passed around to U, almost behind the Sun, where it could not be seen.

In August, although Mercury was well out from the Sun and not excessively far from the Earth, and also the phase was just about half full, the brightness of the planet was low because of its relatively great distance from the Sun.

During 1905 the corresponding aspects of the planet will occur about two weeks earlier than in 1904 and so the brightness will not be quite the same. It will, however, be very nearly the same in August.

Venus is evening star, seen toward the south-west soon after sunset. Her brightness will increase from sixty-two to seventy-two during November. The phase of the planet is gibbous decreasing from 0.86 to 0.79 during the month.

The orbit of Venus is so nearly circular that her brilliancy is very nearly the

same at the corresponding aspects of the planet.

Mars is morning star rising in the east between three and four hours before the Sun. The planet is slowly approaching the Earth but is now more than twice as far away as the Sun, so that it is not a very conspicuous star.

Jupiter is near the meridian at ten o'clock in the evening and is between seven and eight degrees north of the equator so that it is in very good position for observation. The four satellites and the more prominent belts of the planet are easily seen with a quite small telescope so that is a favorite object for amateur study.

Saturn will be at quadrature, 90° east from the Sun Nov. 6 and may be conveniently observed on any clear evening in November, the best time being about six o'clock when the planet is not far from the meridian.

Uranus is approaching superior conjunction and so will not be visible during November.

Neptune may be observed after midnight in the constellation Gemini, among the faint stars about 4° east of the star μ.

The Moon.

Phases. 1904		Rises. h m	Sets. h m
		(Central Standard Time at Northfield. Local Time 13m less.)	
Nov. 7	New Moon	6 44 A. M.	5 23 P. M.
14	First Quarter	12 56 P. M.	11 35 "
22-23	Full Moon	4 52 "	7 32 A. M.
29-30	Last Quarter	11 37 P. M.	1 02 P. M.

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N pt. °	EMERSION. Washington M. T. h m	Angle f'm N pt. °	Duration. h m
Nov. 4	38 Virginis	6.2	15 26	75	16 10	324	0 44
20	65 Ceti	4.5	3 56	34	4 43	287	0 47
20	25 Arietis	7.3	13 28	58	14 40	269	1 12
23	B.A.C. 1526	5.8	9 03	76	10 17	256	1 14
24	130 Tauri	5.5	6 38	112	7 24	231	0 46
25	W.B. (2) vi, 1630	6.2	16 30	115	17 44	263	1 14
26	B.A.C. 2649	6.3	15 35	102	16 58	284	1 23
26	5 Cancri	6.4	17 31	67	18 29	324	0 58
30	89 Leonis	6.2	12 06	106	12 59	286	0 53

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

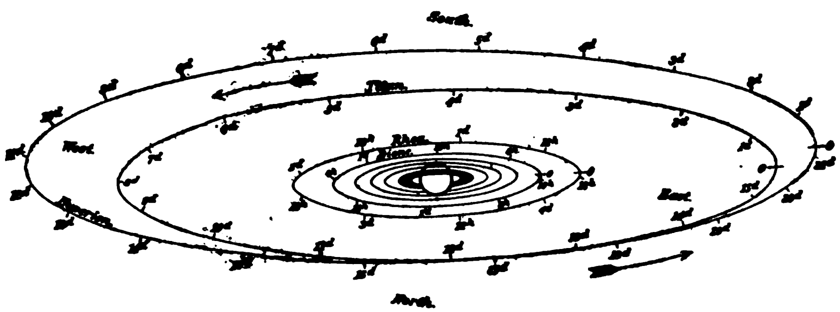
	h m			h m	
Nov. 1	2 59 A. M.	I Tr. In.	Nov. 3	2 05 A. M.	II Ec. Re.
	3 19 "	I Sh. Tr.		2 40 "	III Tr. In.
2	12 13 "	I Oc. Dis.	4	5 35 P. M.	II Tr. In.
	2 46 "	I Ec. Re.		6 02 "	I Tr. Eg.
	9 25 P. M.	I Tr. In.		6 27 "	II Sh. In.
	9 48 "	I Sh. In.		6 30 "	I Sh. Eg.
	10 52 "	II Oc. Dis.		8 00 "	II Tr. Eg.
	11 36 "	I Tr. Eg.		8 57 "	II Sh. Eg.
3	12 01 A. M.	I Sh. Eg.	6	5 54 "	III Oc. Re.

Phenomena of Jupiter's Satellites.—Continued.

Date	h	m		Phenomenon
Nov. 6	6	11	P. M.	III Ec. Dis.
	7	56	"	III Ec. Re.
9	1	58	A. M.	I Oc. Dis.
	11	9	P. M.	I Tr. In.
	11	43	"	I Sh. In.
10	1	07	A. M.	II Oc. Dis.
	1	21	"	I Tr. Eg.
	1	56	"	I Sh. Eg.
	8	24	P.M.	I Oc. Dis.
	11	11	"	I Ec. Re.
11	5	35	"	I Tr. In.
	6	12	"	I Sh. In.
	7	47	"	I Tr. Eg.
	7	52	"	II Tr. In.
	8	24	"	I Sh. Eg.
	9	06	"	II Sh. In.
	10	18	"	II Tr. Eg.
	11	35	"	II Sh. Eg.
12	5	40	"	I Ec. Re.
13	5	58	"	II Ec. Re.
	7	31	"	III Oc. Dis.
	9	18	"	III Oc. Re.
	10	14	"	III Ec. Dis.
	11	57	"	III Ec. Re.
17	12	54	A. M.	I Tr. In.
	1	38	"	I Sh. In.
	3	06	"	I Tr. Eg.
	10	10	P. M.	I Oc. Dis.
18	1	06	A. M.	I Ec. Re.
	7	20	P. M.	I Tr. In.
	8	07	"	I Sh. In.
	9	33	"	I Tr. Eg.
Nov. 18	10	11	P. M.	II Tr. In.
	10	19	"	I Sh. Eg.
	11	44	"	II Sh. In.
19	12	38	A. M.	II Tr. Eg.
	2	14	"	II Sh. Eg.
	4	37	P. M.	I Oc. Dis.
	7	35	"	I Ec. Re.
20	4	32	"	II Oc. Dis.
	4	48	"	I Sh. Eg.
	8	34	"	II Ec. Re.
	10	53	"	III Oc. Dis.
21	12	45	A. M.	III Oc. Re.
	2	16	"	III Ec. Dis.
24	6	10	P. M.	III Sh. Eg.
	11	57	"	I Oc. Dis.
25	3	2	A. M.	I Ec. Re.
	9	07	P. M.	I Tr. In.
	10	02	"	I Sh. In.
	11	20	"	I Tr. Eg.
26	12	14	A. M.	I Sh. Eg.
	12	32	"	II Tr. In.
	2	23	"	II Sh. In.
	6	24	P. M.	I Oc. Dis.
	9	31	"	I Ec. Re.
27	4	30	"	I Sh. In.
	5	46	"	I Tr. Eg.
	6	43	"	I Sh. Eg.
	6	51	"	II Oc. Dis.
	11	10	"	II Ec. Re.
29	4	12	"	II Tr. Eg.
	6	12	"	II Sh. Eg.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

The Satellites of Saturn.



Mimas. Period 0d 22.6h.

	d	h		
Nov.	3	8.9	P. M.	E
	4	7.5	"	E
	5	6.1	"	E
	6	4.8	"	E
	7	3.5	"	E
	12	7.9	P. M.	W
Nov.	13	6.6	P. M.	W
	14	5.2	"	W
	15	3.9	"	W
	20	8.1	"	E
	21	6.7	"	E
	22	5.4	"	E
Nov.	23	4.0	P. M.	E
	28	8.4	"	W
	29	7.1	"	W
	30	5.7	"	W

The Satellites of Saturn.—(Continued.)

Enceladus. Period $1^{d}\ 8.9^{h}$.

Nov. 2	8.4	A. M.	E	Nov. 11	10.6	P. M.	E	Nov. 21	12.9	P. M.	E
3	5.3	P. M.	E	13	7.5	A. M.	E	22	9.8	"	E
5	2.2	A. M.	E	14	4.4	P. M.	E	24	6.7	A. M.	E
6	11.1	"	E	16	1.3	A. M.	E	25	3.6	P. M.	E
7	7.9	P. M.	E	17	10.2	"	E	27	12.5	A. M.	E
9	4.8	A. M.	E	18	7.1	P. M.	E	28	9.4	"	E
10	1.7	P. M.	E	20	4.0	A. M.	E	30	6.3	P. M.	E

Tethys. Period $1^{d}\ 21.3^{h}$.

Nov. 2	1.5	P. M.	E	Nov. 13	9.5	P. M.	E	Nov. 25	5.4	"	E
4	10.9	A. M.	E	15	6.8	"	E	27	2.7	"	E
6	8.2	"	E	17	4.1	"	E	29	12.1	"	E
8	5.5	"	E	19	1.4	"	E	30	9.4	P. M.	E
10	2.8	"	E	21	10.8	A. M.	E				
12	12.1	"	E	23	8.2	"	E				

Dione. Period $2^{d}\ 17.7^{h}$.

Nov. 2	5.9	A. M.	E	Nov. 13	4.8	A. M.	E	Nov. 24	3.6	A. M.	E
4	11.7	P. M.	E	15	10.5	P. M.	E	26	9.2	P. M.	E
7	5.4	"	E	18	4.2	"	E	29	2.9	"	E
10	11.1	A. M.	E	21	9.9	A. M.	E				

Rhea. Period $4^{d}\ 12.5^{h}$.

Nov. 5	11.5	A. M.	E	Nov. 14	12.4	P. M.	E	Nov. 23	1.5	P. M.	E
9	11.9	P. M.	E	19	12.9	A. M.	E	28	2.0	A. M.	E

Titan. Period $15^{d}\ 23.3^{h}$.

Nov. 3	8.3	A. M.	W	Nov. 15	8.5	A. M.	I	Nov. 27	4.5	A. M.	E
7	4.3	"	S	19	7.3	"	W				
11	5.5	"	E	23	3.3	"	S				

Hyperion. Period $21^{d}\ 7.6^{h}$.

Nov. 4.1	W	Nov. 13.9	E	Nov. 25.3	W
9.0	S	19.6	I	30.2	S

Iapetus. Period $79^{d}\ 22.1^{h}$.

Oct. 25.5	I	Nov. 15.2	W	Dec. 6.3	S

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

Designation	Discovered by	Discovered at	Greenwich M. T.	h m	R. A. h m	Decl. ° ′	Mag.
1904 OK	Götz	Heidelberg	1904 July 18	10 10.6	21 13.5	−13 40	12.2
OL	Wolf	"	Aug. 2	10 30.1	21 25.3	− 6 52	11.9
OM	Wolf	"	Aug. 2	10 30.1	21 21.9	− 4 47	11.5
ON	Wolf	"	Aug. 3	10 43.1	21 10.6	− 6 58	13.2
OO	Wolf	"	Aug. 4	10 51.9	21 55.0	− 4 39	13.0
OP	Wolf	"	Aug. 14	13 13.0	22 24.9	+ 4 35	13.5
OQ	Götz, Kopff	"	Aug. 15	12 56.5	0 7.8	− 3 34	11.8

Comet and Asteroid Notes.—(Continued).

Encke's Comet.—Encke's Periodic Comet has been observed on its return by Kopff at Koenigstuhl on Sept. 11.529 Greenwich mean time in R.A. $1^h\ 46^m\ 16^s$ and Decl. + 25° 24′. The comet is very faint.

A serious error was allowed to slip into the ephemeris of Encke's comet in our last number. The sign of the declination should be + instead of −. The same error is found in the ephemeris of Comet *a* 1904.

VARIABLE STARS.

Approximate Magnitudes of Variable Stars Sept. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	15.5 *f*	R Camel.	14	25.1	+84	17	10 *d*
T Cassiop.	0	17.8	+55	14	9 *i*	R Bootis	14	32.8	+27	10	12.5
R Androm.	0	18.8	+38	1	14 *f*	S Librae	15	15.6	−20	2	11.5*d*
S Ceti	0	19.0	− 9	53	8	S Serpentis	15	17.0	+14	40	8 *i*
S Cassiop.	1	12.3	+72	5	16 *f*	S Coronae	15	17.3	+31	44	11.7*d*
R Piscium	1	25.5	+ 2	22	7.5	S Urs. Min.	15	33.4	+78	58	8.8 *i*
R Trianguli	1	31.0	+33	50	8 *i*	R Coronae	15	44.4	+28	28	6.0
U Persei	1	52.9	+54	20	11 *d*	V "	15	45.9	+39	52	10.7*d*
R Arietis	2	10.4	+24	36	8.7d	R Serpentis	15	46.1	+15	26	7.8*d*
o Ceti	2	14.3	− 3	26	11	R Herculis	16	1.7	+18	38	9.5 *i*
S Persei	2	15.7	+58	8	8 *i*	R Scorpii	16	11.7	−22	42	*f*
R Ceti	2	20.9	− 0	38	12	S "	16	11.7	−22	39	*f*
U "	2	28.9	−13	35	6 *i*	U Herculis	16	21.4	+19	7	11.5*d*
R Persei	3	23.7	+35	20	12	W Herculis	16	31.7	+37	32	11 *i*
R Tauri	4	22.8	+ 9	56	14 *f*	R Draconis	16	32.4	+66	58	12.5
S "	4	23.7	+ 9	44	*f*	S Herculis	16	47.4	+15	7	7
R Aurigæ	5	9.2	+53	28	13 *d*	R Ophiuchi	17	2.0	−15	58	7
U Orionis	5	49.9	+20	10	9.7*d*	T Herculis	18	5.3	+31	0	9.5 *i*
R Lyncis	6	53.0	+55	28	9 *i*	R Scuti	18	42.2	− 5	49	7 *d*
R Gemin.	7	1.3	+22	52	*f*	R Aquilae	19	1.6	+ 8	5	10.5*d*
S Canis Min.	7	27.3	+ 8	32	*s*	R Sagittarii	19	10.8	−19	29	10.2 *i*
R Cancri	8	11.0	+12	2	*s*	S "	19	13.6	−19	12	11 *d*
V "	8	16.0	+17	36	*s*	R Cygni	19	34.1	+49	58	15 *d*
S Hydrae	8	48.4	+ 3	27	*s*	RT "	19	40.8	+48	32	*f*
T "	8	50.8	− 8	46	*s*	X "	19	46.7	+32	40	9.3 *i*
R Leo. Min.	9	39.6	+34	58	*s*	S Cygni	20	3.4	+57	42	12.6*d*
R Leonis	9	42.2	+11	54	*s*	RS "	20	9.8	+38	28	7.7 *i*
R Urs. Maj.	10	37.6	+69	18	9.5*d*	R Delphini	20	10.1	+ 8	47	8
R Comae	11	59.1	+19	20	8	U Cygni	20	16.5	+47	35	7.5
T Virginis	12	9.5	− 5	29	*s*	V "	20	38.1	+47	47	12.5*d*
R Corvi	12	14.4	−18	42	*s*	T Aquarii	20	44.7	− 5	31	8
Y Virginis	12	28.7	− 3	52	*f*	R Vulpec.	20	59.9	+23	26	8.5 *i*
T Urs. Maj.	12	31.8	+60	2	11 *d*	T Cephei	21	8.2	+68	5	9.7*d*
R Virginis	12	33.4	+ 7	32	*s*	S "	21	36.5	+78	10	10.5*d*
S Urs. Maj.	12	39.6	+61	38	11.5*d*	S Lacertae	22	24.6	+39	48	10 *d*
U Virginis	12	46.0	+ 6	6	11.5*d*	R "	22	38.8	+41	51	12 *d*
V "	13	22.6	− 2	39	*s*	S Aquarii	22	51.8	−20	53	12
R Hydrae	13	24.2	−22	46	*s*	R Pegasi	23	1.6	+10	0	7
S Virginis	13	27.8	− 6	41	*s*	S "	23	15.5	+ 8	22	13
R Can. Ven.	13	44.6	+40	2	9.5*d*	R Aquarii	23	38.6	−15	50	10.4
S Bootis	14	19.5	+54	16	8.4 *i*	R Cassiop.	23	53.3	+50	50	12.8*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

From observations made at the McCormick, Halsted and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U Cephei.

	d	h
Nov.	2	10
	4	21
	7	9
	9	21
	12	9
	14	21
	17	9
	19	20
	22	8
	24	20
	27	8
	29	20

Z Persei.

Nov.	1	2
	4	3
	7	5
	10	6
	13	7
	16	9
	19	10
	22	11
	25	13
	28	14

Algol.

Nov.	2	18
	5	15
	8	12
	11	9
	14	5
	17	2
	19	23
	22	20
	25	17
	28	13

λ Tauri.

Nov.	1	23
	5	22
	9	21
	13	20
	17	18
	21	17
	25	16
	29	15

R Canis Maj.

	d	h
Nov.	2	2
	3	6
	4	9
	5	12
	6	16
	7	19
	8	22
	10	1
	11	5
	12	8
Nov.	13	11
	14	14
	15	18
	16	21
	18	0
	19	3
	20	7
	21	10
	22	13
	23	16
	24	20
	25	23
	27	2
	28	6
	29	9
	30	12

V Puppis.

	d	h
Nov.	1	23
	3	10
	4	20
	6	7
	7	18
	9	5
	10	16
	12	3
	13	14
	15	1
	16	12
	17	23
	19	10
	20	20
	22	8
	23	18
	25	5
	26	16
	28	3
	29	14

S Cancri.

Nov.	7	11
	16	23
	26	10

S Antliæ.

	d	h
Nov.	1	23
	2	22
	3	21
	4	21
	5	20
	6	19
	7	19
	8	18
	9	17
	10	17
	11	16
Nov.	12	15
	13	15
	14	14
	15	13
	16	13
	17	12
	18	11
	19	11
	20	10
	21	9
	22	9
	23	8
	24	7
	25	7
	26	6
	27	5
	28	5
	29	4
	30	3

S Velorum.

Nov.	4	9
	10	7
	16	6
	22	4
	28	2

W. Urs. Maj.

Nov.	1-3	10
	4-30	11

RR Velorum.

Nov.	1	22
	3	19
	5	15
	7	12
	9	8
	11	4
	13	1
	14	22
	16	18
	18	15
	20	11
	22	8
	24	4
	26	1
	27	21
	29	18

Z Draconis.

	d	h
Nov.	1	21
	3	6
	4	14
	5	23
	7	8
	8	16
	10	1
	11	9
Nov.	12	18
	14	3
	15	11
	16	20
	18	4
	19	13
	20	21
	22	6
	23	15
	24	23
	26	8
	27	16
	29	1
	30	9

Z Herculis.

Nov.	2	16
	4	13
	6	15
	8	12
	10	15
	12	12
	14	15
	16	12
	18	16
	20	12
	22	15
	24	12
	26	14
	28	11
	30	14

RS Sagittarii.

Nov.	1	13
	3	23
	6	8
	8	19
	11	5
	13	15
	16	1
	18	11
	20	21
	23	7
	25	17
	28	3
	30	13

RX Herculis.

	d	h
Nov.	1	4
	2	1
	2	22
	3	20
	4	17
	5	15
	6	12
	7	9
	8	6
Nov.	9	4
	10	1
	10	23
	11	20
	12	17
	13	15
	14	12
	15	9
	16	7
	17	4
	18	1
	18	23
	19	20
	20	17
	21	15
	22	12
	23	9
	24	7
	25	4
	26	1
	26	23
	27	20
	28	17
	29	15
	30	12

RV Lyræ.

Nov.	3	6
	6	20
	10	10
	14	1
	17	15
	21	6
	24	20
	28	10

U Sagittæ.

Nov.	4	0
	7	9
	10	18
	14	3
	17	12
	20	22
	24	7
	27	16

SY Cygni.

Nov.	3	22
	9	22
	15	22
	21	22
	27	22

SW Cygni.

Nov.	4	23
	9	13
	14	3

Minima of Variable Stars of the Algol Type.—Continued.

SW Cygni.

	d	h
Nov.	18	17
	23	6
	27	20

UW Cygni.

	d	h
Nov.	2	23
	5	10
	9	21
	13	8
	16	19
	20	6
	23	16
	27	3
	30	14

W Delphini.

	d	h
Nov.	4	16
	9	11
	14	6
	19	2
	23	21
	28	17

VV Cygni.

	d	h
Nov.	1	2
	2	14
	4	1
	5	13
	7	0
	8	12

VV Cygni.

	d	h
Nov.	9	23
	11	11
	12	22
	14	10
	15	21
	17	8
	18	20
	20	7
	21	19
	23	6
	24	18
	26	5
	27	17
	29	4
	30	15

VW Cygni.

	d	h
Nov.	2	2
	10	13
	18	23
	27	9

Y Cygni.

	d	h
Nov.	1	21
	3	12
	4	21
	6	12
	7	21
	9	12
	10	21
	12	12

Y Cygni.

	d	h
Nov.	13	21
	15	12
	16	21
	18	12
	19	21
	21	12
	22	21
	24	12
	25	21
	27	12
	28	21
	30	12

UZ Cygni.

	d	h
Nov.	23	0

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h
Nov.	1- 5	6	Nov.	14-21	8	Nov.	29-30	10
	6-13	7		22-29	9			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

	d	h		d	h		d	h		d	h
Nov.	1	22	Nov.	9	18	Nov.	17	14	Nov.	25	11
	3	0		10	21		18	17		26	14
	4	3		12	0		19	20		27	17
	5	6		13	3		20	23		28	20
	6	9		14	6		22	2		29	22
	7	12		15	9		23	5		31	1
	8	15		16	11		24	8			

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
Nov.	1	13	Nov.	9	18	Nov.	17	22	Nov.	26	2
	2	14		10	18		18	22		27	3
	3	14		11	19		19	23		28	3
	4	15		12	19		21	0		29	4
	5	15		13	20		22	0		30	4
	6	16		14	20		23	1			
	7	17		15	21		24	1			
	8	17		16	21		25	2			

Variable Stars of Short Period not of the Algol Type.

	Minimum.			Maximum.				Minimum.		Maximum.	
		d	h		d	h		d	h	d	h
W Geminorum	Nov.	1	11	Nov.	4	2	δ Cephei	2	7	3	16
V Velorum		1	12		2	11	X Cygni	2	17	8	22
U Sagittarii		2	0		4	23	TX Cygni	3	1	8	4

Variable Stars of Short Period not of the Algol Type.—(Continued.)

		Minimum. d	h	Maximum. d	h			Minimum. d	h	Maximum. d	h
ζ Geminorum	Nov.	3	19	8	19	R Crucis	Nov.	17	14	18	23
κ Pavonis		3	20	7	15	S Muscae		17	15	21	2
S Crucis		3	21	5	9	TX Cygni		17	18	22	21
T Velorum		3	22	5	7	T Velorum		17	20	19	5
Y Sagittarii		4	7	6	2	S Crucis		17	22	19	10
T Vulpeculae		4	14	5	23	T Vulpeculae		17	22	19	7
SU Cygni		4	17	6	1	δ Cephei		18	9	19	18
T Crucis		5	2	7	3	T Crucis		18	13	20	14
W Sagittarii		5	3	8	3	V Velorum		19	0	19	23
V Velorum		5	21	6	20	X Cygni		19	2	25	7
R Crucis		5	22	7	7	β Lyræ		19	3	22	10
X Sagittarii		6	1	8	23	X Sagittarii		20	1	22	22
β Lyræ		6	5	9	12	SU Cygni		20	2	21	10
η Aquilae		6	10	8	19	W Sagittarii		20	7	23	7
U Aquilae		6	14	8	18	V Carinae		20	13	22	17
U Vulpeculae		6	16	8	19	U Aquilae		20	15	22	19
V Carinae		7	3	9	7	η Aquilae		20	18	23	3
δ Cephei		7	15	9	0	Y Sagittarii		21	15	23	10
S Muscae		7	23	11	10	U Sagittarii		22	6	25	5
S Sagittæ		8	4	11	14	T Vulpeculae		22	8	23	17
W Virginis		8	7	16	12	T Velorum		22	11	23	20
SU Cygni		8	13	9	21	S Crucis		22	15	24	3
T Velorum		8	13	9	22	U Vulpeculae		22	15	24	18
S Crucis		8	13	10	1	V Velorum		23	9	24	8
U Sagittarii		8	18	11	17	R Crucis		23	10	24	19
T Vulpeculae		9	1	10	10	δ Cephei		23	18	25	3
W Geminorum		9	5	11	20	SU Cygni		23	22	25	6
Y Sagittarii		10	2	11	21	ζ Geminorum		24	3	29	3
V Velorum		10	6	11	5	W Geminorum		24	17	27	8
R Crucis		11	18	13	3	S Sagittae		24	23	28	9
T Crucis		11	20	13	21	T Crucis		25	7	27	8
SU Cygni		12	9	13	17	W Virginis		25	13	33	18
β Lyræ		12	16	15	18	β Lyrae		25	14	28	16
W Sagittarii		12	17	15	17	T Monocerotis		25	23	34	8
δ Cephei		13	0	14	9	T Vulpeculae		26	19	28	4
X Sagittarii		13	1	15	23	T Velorum		27	2	28	11
T Velorum		13	5	14	14	X Sagittarii		27	2	29	23
S Crucis		13	6	14	18	V Carinae		27	5	29	9
T Vulpeculae		13	10	14	19	S Crucis		27	7	28	19
η Aquilæ		13	14	15	23	S Muscae		27	7	30	18
U Aquilae		13	15	15	19	Y Sagittarii		27	9	29	4
V Carinae		13	19	15	23	U Aquilae		27	16	29	20
ζ Geminorum		13	23	18	23	V Velorum		27	18	28	17
V Velorum		14	15	15	14	SU Cygni		27	18	29	2
U Vulpeculae		14	16	16	19	W Sagittarii		27	22	30	22
U Sagittarii		15	12	18	11	η Aquilae		27	22	30	7
Y Sagittarii		15	20	17	15	U Sagittarii		29	0	31	23
SU Cygni		16	5	17	13	δ Cephei		29	2	30	11
S Sagittae		16	13	19	20	R Crucis		29	6	30	15
W Geminorum		16	23	19	14	U Vulpeculae		30	15	32	18

Twenty-five New Variables in Aquila.—In *A. N.* 3959 Professor Max Wolf, of Heidelberg gives the positions for 1900.0 of twenty-five new variables found in the constellation Aquila by comparing photographs taken in 1901 and 1903. Charts of all these variables are also given.

Designation	α 1900.0 h	m	s	δ 1900.0 °	′	″	Magnitude 1901	1903
64. 1903	19	27	48.78	+10	18	39.1	11.5	15
65. 1903		30	25.81	+7	02	14.1	14	12.5
66. 1903		33	11.20	+12	33	45.5	< 14	13
67. 1903		34	02.79	+12	02	21.7	13	< 14.5
68. 1903		34	20.15	+11	43	05.0	14.5	11
RV Aquilæ		35	56.75	+9	41	57.2	13	10.5
69. 1903		36	21.56	+7	11	02.8	14	11.5
70. 1903		38	06.17	+13	20	07.4	12.0	14.5
71. 1903		40	21.55	+8	12	11.7	11	< 15
72. 1903		41	47.05	+10	32	23.8	< 15	13.5
73. 1903		41	56.00	+10	13	06.1	< 15	14
74. 1903		42	22.61	+7	23	03.6	13.5	11.5
75. 1903		42	30.19	+12	14	19.5	11.5	< 15
76. 1903		42	49.38	+9	41	56.6	< 15	12.0
77. 1903		43	39.78	+11	16	33.0	10.0	12.0
78. 1903		44	34.78	+12	07	07.4	11.0	13.0
79. 1903		46	00.21	+12	33	57.9	14	11.5
80. 1903		46	15.30	+12	58	00.0	11	< 14
81. 1903		48	42.38	+9	06	37.3	12	14
82. 1903		48	59.37	+10	44	05.1	12	13
83. 1903		49	06.26	+9	24	00.8	11	13
84. 1903		49	24.82	+7	21	01.4	12.5	11.5
85. 1903	19	49	32.68	+7	44	39.8	13	< 14
111. 1904	19	33	40.66	+10	22	02.1	13	< 15
112. 1904	19	34	12.46	+10	16	35.7	12.7	11.2

New Variables Discovered at Harvard.—*Circular* 79 of Harvard College Observatory gives the positions of seventy-six new variables found by Miss Leavitt in her examination of the Harvard photographic plates. Nine of them are in the region of the Orion Nebula, ten in the vicinity of η Carinæ and the remainder in the lesser Magellanic cloud in the southern heavens. Six other new variables are announced in *Circular* No. 80 and 152 in *Circular* No. 82, the latter number being all within the Large Magellanic cloud. The two long lists of variables in the Magellanic clouds have not been numbered by the Variable Star Committee and since the stars are all in the south polar regions of the sky we shall omit them here. The remaining variables are as follows:

Designation.	α 1900			δ 1900		Brightness.	
114. 1904 Orionis	5	24	01	−6	11.3	11.6	< 15.4
115. 1904 "	5	25	13	−4	33.9	12.4	13.1
116. 1904 "	5	27	05	−5	00.7	10.0	11.0
117. 1904 "	5	27	08	−2	53.7	9.0	11.4
118. 1904 "	5	30	25	−5	24.8	11.4	12.5
119. 1904 "	5	30	33	−6	51.7	12.8	13.5
120. 1904 "	5	32	22	−9	38.6	8.0	10.2
121. 1904 "	5	33	32	−2	48.0	11.6	13.2
122. 1904 "	5	33	34	−2	47.5	11.4	14.2
133. 1904 Aurigæ	6	04.8		+43	11	Variation 2.5^m	
123. 1904 Carinæ	10	16.8		−60	57	10.0	11.5
124. 1904 "	10	20.9		−60	24	10.2	12.2
125. 1904 "	10	34.6		−58	41	11.4	13.0
126. 1904 "	10	34.7		−60	16	13.4	< 15.1
127. 1904 "	10	36.4		−57	25	11.1	12.8
128. 1904 "	10	47.0		−59	49	13.1	< 15.1
129. 1904 "	10	49.9		−57	59	12.6	14.9
130. 1904 "	10	50.2		−57	52	13.7	< 15.1
131. 1904 "	10	50.4		−58	15	13.4	14.5
132. 1904 "	10	51.3		−60	24	9.2	10.2
134. 1804 Ursæ maj.	12	35.8		+56	23	8.2	Varies 1.0^m
135. 1904 Centauri	14	43.3		−42	05		Varies 2.5^m
136. 1904 Ophiuchi	17	29.8		+7	19	9.2	Varies 2.3^m
137. 1904 Sagittarii	19	13.4		−31	54	9.7	Varies 1.5^m
138. 1904 Microscopii	21	17.5		−41	07		Varies 3.0^m

New Variables 139.1904 Sagittarii and 140.1904 Scuti.—These are two faint stars discovered by R. S. Dugan on photographs taken at Heidelberg. The first was below 13.5 or 14.5 magnitude on four plates taken in 1894 and 1901 but appears of the twelfth magnitude on June 21, 1904. The second appears on several plates as about 11.5 magnitude but on June 29, July 2, July 6, 1900 and June 21, 1900 was below 14.5. The positions are

	α 1900.0	δ 1900.0
139.1904	$18^h\ 40^m\ 02^s.49$	$-17°\ 24'\ 14''.3$
140.1904	18 42 31 52	−12 14 22 .5

New Variable 141.1904 Geminorum.—This was found by Professor Wolf of Heidelberg. It is invisible on plates taken Dec. 22, 1891, Jan. 7, 1896, Jan. 8, 1902, Jan. 17, 1603, but is found with magnitude 11.2 on Dec. 22, 1892 and 10.5 on April 20, 1903. Its position is

α 1900.0	δ 1900.0
$7^h\ 11^m\ 56^s.06$	$+24°\ 06'\ 05''.4$

It forms a small equilateral triangle with two eleventh magnitude stars.

New Variable 142.1904 Pegasi.—In *A. N.* 3964 Professor K. Graff announces this new variable which is nearly on a parallel with and about 8^s preceding the star BD + 11°,4757. It is the southern component of a close double star. On July 10, 1904 it was bright, about 9.4 magnitude, while on Aug. 2 it had sunk below its 11.5 mag. companion. Its position is

α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
$22^h\ 06^m\ 57^s$	$+11°\ 59'.1$	$22^h\ 09^m\ 09^s$	$+12°\ 12'.4$

Eleven New Variables 143-153.1904 in Vulpecula.—By comparing two plates taken with the Bruce telescope at Heidelberg on June 27, 1903 and July 8, 1904, Professor Max Wolf has discovered eleven new variables in the eastern part of the constellation Vulpecula. The following table gives their positions for 1900.0 as measured by Professor Wolf and their approximate magnitudes as shown on the two plates:

	α 1900.0			δ 1900.0			June 27	July 8
	h	m	s	°	′	″	1903.	1904.
143. 1904	20	32	00.54	+ 23	31	00 2	13.2	11.2
144. 1904		32	18.88	+ 22	33	23.2	10.8	< 15.
145. 1904		32	41.95	+ 25	57	55.3	15	12.0
146. 1904		34	29.77	+ 22	54	23.6	10.3	10.8
147. 1904		34	51.98	+ 23	08	34.4	10.3	14.
148. 1904		35	20.60	+ 26	54	44.2	14.0	11.9
149. 1904		37	25.50	+ 26	56	50.6	12.0	13.5
150. 1904		51	33.52	+ 26	17	50.7	11.0	< 15
151. 1904		52	20.25	+ 23	11	35.5	11.9	< 15
152. 1904		53	07.02	+ 27	28	13.9	9.9	11.2
153. 1904	20	53	23.29	+ 25	07	17.6	13.5	12.3

Charts of the vicinity of each of these variables are given in the *Astronomische Nachrichten* No. 3965. If these charts will be of value to any considerable number of our readers we shall be glad to publish them in a later number of Popular Astronomy, but we shall not do so unless there is some expressed desire for them. We shall be glad to hear from the variable star observers on this point.

New Variable 154.1904 Cygni.—Professor W. Ceraski, in *A. N.* 3965, calls attention to a new variable in Cygnus, which is probably of the Algol type. On twenty plates, in the interval 1895-1903, the star is of about the same brightness, 9.3 magnitude, except on one taken Aug. 17, 1901, $11^h 55^m - 14^h 5^m$ Moscow mean time, when it was as faint as 12.5 magnitude. Visual observations of the star during this year indicate a constant brightness, about 9.3^m, except on Aug. 6 and 16 when it was noted to be faint. The star is BD + 41° 3595 and its position is

α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
$19^h 59^m 03^s.4$	$+41° 10'.7$	$20^h 00^m 36^s.0$	$+41° 18'.2$

GENERAL NOTES.

Saturn

The Ninth Satellite of ~~Mars~~.—We have received the extended paper by William H. Pickering on the ninth satellite of Mars. It deserves a fuller and more detailed notice than we now have space to give. A review of it will appear in our next issue.

The brilliant, detonating meteorite that is believed to have fallen not many miles from Northfield, Minn., July 26, 1904, has not yet been found, as far as we know. Professor N. H. Winchell's interesting notes elsewhere printed gives the best and latest information.

Photographic Work in the Rocky Mountains.—On account of the forest fires west of our observing station, we were unable to complete the work planned for the months of July and August last. By the generous courtesies of the general officers of the Great Northern Railway Company, we will return in a few days to do some more of the original plan needed before another year.

Manora Observatory.—In a circular accompanying the last issue of the *Astronomische Rundschau*, notice is given of the purpose to sell the Manora Observatory, instruments and library, at a moderate price, during the year 1905. The telescope is spoken of as one of great excellence. Apply to Manora-Sternwarte Lussenpiccolo (Istri).

Phœbe, Ninth Satellite of Saturn.—A search for Phœbe, the ninth satellite of Saturn was made on August 6, 1904, with the 40-inch Yerkes Telescope, by Professor Barnard, and Professor Turner of Oxford. An object was found resembling a star at 15.5 or 16.0 magnitude. Its apparent place $16^h 0^m$, Greenwich Mean Time, was R. A. $21^h 23^m 1.0^s$, Decl. $-16° 36' 6''$. On Sept. 8, 1904, Professor Barnard found that this object was missing. There is no star in this position shown on photographs taken with the Bruce Telescope, on which Phœbe is visible. According to the ephemeris, (*Harvard Annals* LIII, 72), the approximate position of Phœbe on August 8, 1904, was R. A. $21^h 23^m 0^s$ Decl. $-16° 36' 4''$. This is, therefore, probably the first visual observation of the ninth satellite of Saturn. EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, *Bulletin*, No. *157*.
Cambridge, Mass., Sept. 8, 1904.

A telegram has been received at the Harvard College Observatory from Prof.

E. B. Frost at Yerkes Observatory stating that Phœbe. the ninth satellite of Saturn, was observed by Professor Barnard, September 12, at 12^h 36^m Greenwich Mean Time in R. A 21^h 12^m $29^s.5$, and Decl $-17° 25' 55''$. Its motion was toward the south-west and its magnitude 16.7.

Bulletin, No. 159.

CAMBRIDGE, Sept. 13, 1904.

The Crocker Eclipse Expedition of Lick Observatory.—William H. Crocker an intelligent and bountiful helper in many eclipse expeditions for Lick Observatory, will bear the expenses of three expeditions to observe the total solar eclipse of the Sun, August 30, 1905. As far as known the program is as follows:

Labrador. A photographic search for intramercurial planets, in the sky, 8½° wide, in the direction of the solar equator, from 4° below the Sun to 15° above it. To make photographs of the Corona with a camera of five inches aperature and forty feet focus.

Spain. Photographic intramercurial search, 9¼° wide, in the direction of the solar equator, from 14° below to 14° above the Sun. To photograph the Corona as mentioned above. To observe the Corona for polarized light. To make spectrograms with moving plate holders for a continuous record between second and third contacts. To specialize in this kind of work on the "green line" and the "flash."

Egypt. Photographic intramercurial search same as in Labrador. The study of the Corona in the same way. Also the photography of the general spectrum of the Corona. Minor details of the work of these expeditions will doubtless be published later.

Constitution of Matter.—It is reported that there have been learned discussions at recent Cambridge Association meetings in regard to the constitution of matter. Some physicists holding that our sixty-six chemical elements should be greatly reduced to just what number no one dares to say. Some bold theorists outside of the association named are saying that all these elements so-called will be reduced ultimately to one. When the magnetic properties of matter are better understood and the principles of light rays are more fully comprehended, then chemically speaking, one element in nature endowed with polarity may be the basis of the new chemistry. But at the present time we are a long, long way from that state of physical science, and especially in spectroscopy.

The Lives of Tycho Brahe and Copernicus by Gassendo.—A short time since I picked up in a second-hand book store what I consider to be a rare book. It is the lives of Tycho Brahe and Copernicus, by Petro Gassendo. The book was written in Latin and published in Paris by Mathurini Dupius in the year 1654. It is therefore 250 years old. The pages are 9x6½ inches in size, and the book is bound in leather. It has full page portraits of Tycho and Copernicus, as well as cuts illustrating two different theories of the solar system.

The book opens with a preface of fifty pages, after which comes the life of Tycho in six chapters, preceded by a full page portrait, and occupying 258 pages. Then follow an appendix, the funeral oration, two eulogistic poems, an account of Tycho's work, including three pages of tables of his stellar observations, and an index—all taking up seventy-two pages. Next comes the life of Copernicus,

preceded by a full page portrait. This is very much shorter than Tycho's life, and occupies but fifty-one pages. Then follow short lives of George Peurbache and Johannes Regiomontani, occupying fifty-seven pages. An index of twelve pages finishes the book, making a total of 500 pages.

A former owner of the book has made some marginal corrections and notes in French and in Latin, which adds somewhat to its interest.

I send this brief account of the book, thinking it might be of interest to the readers of POPULAR ASTRONOMY, and in the hope that some reader may know something of the history of this work, which is a fine example of the printer's art of that time, and shows considerable enterprise on the part of some one to bring out a work of that kind. ALBERT I. BROOKS.

BROOKLYN, N. Y., Sept. 1904.

Clock Stopped by Lightning.—In *A. N.* 3964 Dr. Ernst Hartwig gives an interesting account of the stopping of the chief clock of the Bamberg Observatory by the influence of lightning. The clock is suspended on a pillar in the basement of the meridian room, the walls of which are of wrought iron. A lightning rod on the dome of the observatory is connected with the walls of the meridian room as well as with a metal plate deep in the ground. Four insulated wires imbedded in lead cables run from the clock to the meridian room, passing through the iron walls, two of the wires being connected with a microphone standing on the top of the clock and two with a contact apparatus in the clock. The clock is enclosed in a cylindrical, air-tight glass case, the metal plates at the top and bottom being connected by metal rods.

On the night of May 27 last, during a severe thunder storm, the lightning rod on the dome was struck twice within an interval of 46 seconds and the clock stopped 34 seconds after the second stroke of lightning. Dr. Hartwig at the time was noting the intervals between flashes of lightning and the succeeding reports of the thunder, and thus notes the exact times by the clock of these two flashes with the instantaneous reports as $12^h\ 57^m\ 01^s$ and $12^h\ 57^m\ 47^s$, Middle European time. The clock stopped at $12^h\ 58^m\ 21^s$.

The clock was taken down and carefully examined on the following day and no injury whatever was found, no sign of burning or fusion, and after being set up again it has run as well as before. The conclusion which Dr. Hartwig draws is that the lightning did not pass through the clock but took the course of least resistance through the metal case, and that the pendulum was stopped by being within a powerful electric field.

The clock used for transmitting time signals at Goodsell Observatory has twice been stopped by lightning, which fused the contact points together and thus caught the toothed wheel on the second's shaft, but the Bamberg instance seems to have been entirely different. In these instances at Northfield the lightning did not strike the observatory but the telegraph line some distance away. Recently we have tried to protect the observatory by placing lightning rods on several of the telegraph poles near the building. No serious shock has been noticed within the building since the placing of these lightning rods.

Photographic Brightness of Stars in the Pleiades Group.—In *A. N.* 3964 Mr. R. S. Dugan of the Observatory at Königstuhl-Heidelberg gives accurate positions and the photographic brightness of 350 faint stars in a por-

tion of the Pleiades group. The portion of the group includes about half a degree wide, east and west, and a degree long, north and south, extending from R. A. $3^h\ 41^m\ 30^s$ to $3^h\ 43^m\ 15^s$ and Decl. $+ 23° 05'$ to $+ 24° 15'$. In R. A. it extends approximately from Alcyone to Atlas and Pleione. The faintest stars included in the list are of the 15.3 magnitude on the scale employed. I find by comparing the chart which Mr. Dugan gives that these faintest stars are just barely visible on a photograph taken with the 8-inch Clark refractor at Goodsell Observatory with an exposure of four hours. Seven hour and sixteen hour exposures show many more stars.

Elogy on Sir Isaac Newton.—The English translation of Halley's Preface to the *Principia*, as reprinted in POPULAR ASTRONOMY, Vol. XII, pages 504-506, contains a few typographical errors. There should be exclamation marks after the fifth and sixth lines, viz:—

"Th" Almighty fix'd, when all things good he saw!
Behold the chaste, inviolable law!"

The next to the last line was wholly omitted. Therefore, I repeat the two concluding lines:—

"Newton, who reach'd th' insuperable line,
The nice barrier 'twixt human and divine."

With the above corrections, the reprint practically corresponds with the autographic copy sent me by Mr. Bolton. I deemed the English version a literary curiousity worthy of wider circulation, notwithstanding the opinion of so high an authority as Prof. S. P. Rigaud (d. 1839) that the translation "is not well done." (See "Historical Essay on the First Publication of Sir Isaac Newton's Principia," by S. P. Rigurd, page 86; Oxford, 1838.)

EUGENE FAIRFIELD MCPIKE.

ON HALLEY'S COMET, IN 1835.

P. BRONTE.*

Our blazing guest, long have you been,
To us, and many more, unseen;
Full seventy years have pass'd away
Since last we saw you, fresh and gay—
Time seems to do you little wrong—
As yet, you sweep the sky along,
A thousand times more glib and fast,
Than railroad speed or sweeping blast—
Not so—the things you left behind—
Not so—the race of human kind.
Vast changes in this world have been,
Since by this world you last were seen;
The child, who clapped his hands with joy,
And hailed thee as a shining toy,
Has pass'd, long since, that dusky bourne,
From whence no travellers return;
Or sinking now in feeble age,
Surveys thee as a hoary sage;
Sees thee, a mighty globe serene,

Wide hurried o'er the welkin sheen,
In nebulous or solid state,
For ends both wise, and good, and great:
Or, to adjust and balance true
The shining orbs of ether blue,
Lest, erring in the heavenly plane,
All should to chaos rush again;—
Or, if the sun, as Newton says,
Still issues forth substantial rays,
Emitting from his body bright,
Exhausting sparks of rapid light—
To give him back each spark and ray,
Well gather'd, on thy airy way;
Lest he should sink in wrinkled years,
And leave in night the rolling spheres.
Say, dost thou, then, all things that burn,
Give to the Sun in thy return?
And thus maintain his shining face
In all the pride of youthful grace?
If so, thou art less selfish far,
Than many another shining star—
Less selfish, far, than those below,
Who gaze upon thy brilliant glow;
For here, on earth, both one and all,
We try to rise on others' fall;
And think our lustre shines the best,
When dusky veils obscure the rest.
But Newton sage and others say,
The Sun doth play you *yea* and *nay*;
That, at each point of time, his force
Attracts, repels, thy fiery course;
In contradiction—strange to say—
Lest you should wander from your way,
And that, when he has got thy meed,
He sends you on your way with speed.
Alas! alas! should this be so?
How many suns are here below,
Save that they want both heat and light,
And never shine, by day or night—
Attract—repel—get all they can—
And part with nought to living man!
Some say thou art electric fire,
And hast a tail of plague and ire—
That all along thy airy way
You shed on men a baleful sway;
That on the nations near and far
You sow the seeds of bloody war.
Small need for these thy fatal arts;
For we abound in wrathful hearts,
And cunning heads, and blighting gales,
And martial hands, and fiery tails—
And swift to ill—for ill combine,

With ready skill, surpassing thine.

Thy course is chang'd, as sages say,
And thou hast run a novel way,
Just that the wond'ring world might own
Thou hast a will and way thine own.
In this, fair stranger, we're inclined
To follow thee, and have our mind—
Whate'er sarcastic mortals say,
For we have orbits where to move,
By impulse strong, of hate or love;
And we have ends to answer here,
Though in a dark and narrow sphere.
Since last this earth has seen thy face
Thou hast been wide in many a place,
And many suns and worlds hast known
Besides these orbs we call our own;—
Say, hast thou, in thy leisure hours,
E'er scrutinis'd a world like ours?—
E'er seen such thinking worms of clay,
Run wildly mad in such a way?—
So brief in life—so prone to ill—
So much averse to that great Will,
That speaks in truth and boundless might
And gave thee all thy speed, and light,
And very being—and has said
"Let all things be"—and they were made.

But thou art on thy course, I see,
And wilt not converse deign to me;—
Nor man nor angels by their force
Can for one moment stop thy course;—
The Mighty God Himself alone
Can rein thy speed, and guide thee on.
Then fare thee well, thou mighty star—
Go—do thy errand, near and far.
Ere thou dost here return again,
Few things that now are shall remain.
Tell distant worlds, on whom you shine,
The hand that made thee is divine,—
Round thy wide orbit shed thy rays,
In token of the highest praise
To God, who made thyself and all
The stars around this earthly ball—
Who shall beam forth, in glory bright,
When all creation sets in night.

* HAWORTH, October 20, 1835.

The poem reprinted above was published, perhaps for the first time, in *The Bradfordian*, for August 1st, 1861, and it again appeared in *The Bradford Weekly Telegraph* for August 6, 1904. Of each of these two publications, the former being rare and valuable, a copy has been sent me by Dr. Chas. F. Forshaw, M. A., LL. D., F. R. S. L., F. R. H. S., etc., etc., himself a prominent poet and scholar of Bradford, Yorkshire, England.

EUGENE FAIRFIELD MCPIKE.

CHICAGO, ILLINOIS, Sept. 14, 1904.

Correction.—Line 5, page 472 of our last issue should read "Notices of the Royal Astronomical Society there," and the word "pages," on line 6, should read "papers."

Pages 215-256 should be numbered 515-556.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the tenth of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription will hereafter be sent with the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astrononomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. Appropriate blanks have been prepared and will be sent out generally to secure this important information. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

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Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

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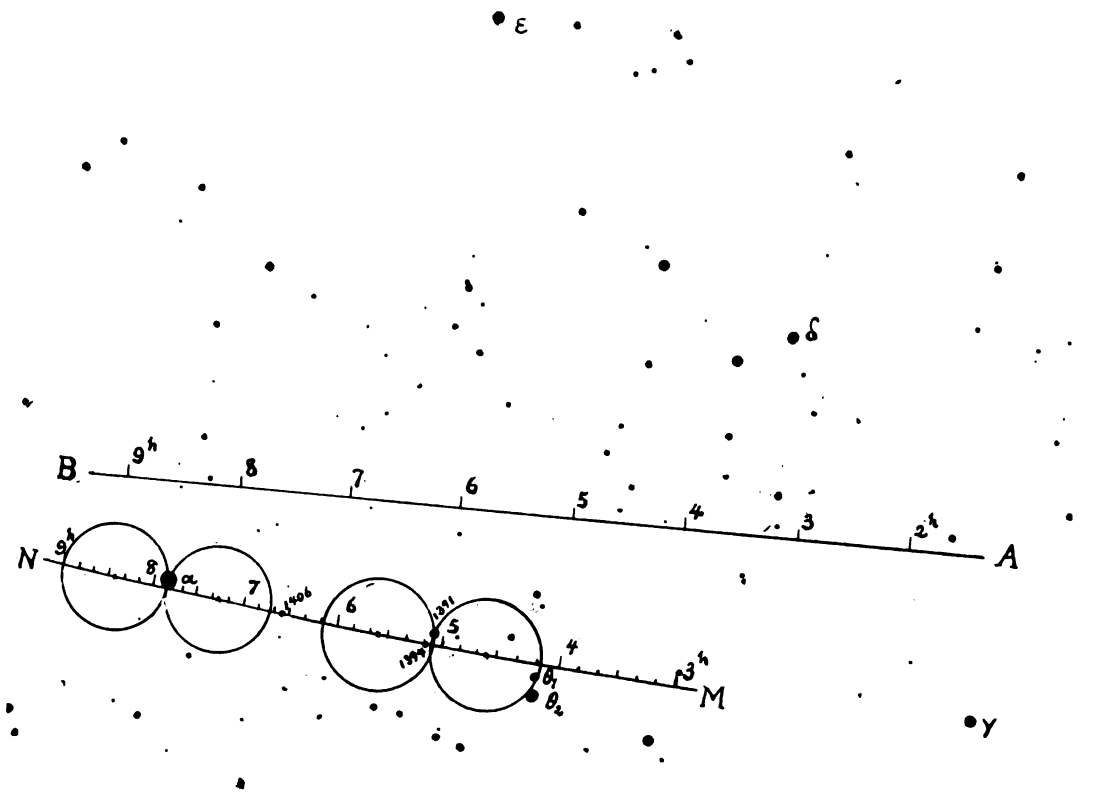
All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.

PLATE XXII.



OCCULTATIONS OF STARS IN THE HYADES, DEC. 20, 1904.

AB represents the apparent path of the moon's center as seen from the center of the earth, MN that seen from Northfield. The hours marked on the diagram are in Central Standard time.

Popular Astronomy.

Vol. XII No. 9. NOVEMBER, 1904. Whole No. 119.

DOUBLE CANALS AND THE SEPARATIVE POWERS OF GLASSES.

PERCIVAL LOWELL.

FOR POPULAR ASTRONOMY.

That the double canals of the planet Mars are not optical products of interference like the spurious disk and rings made by an ordinary star in the focal plane of a telescope appears, both theoretically and practically, from an investigation directed to that end and published in *Bulletin* No. 5 of this observatory. In other words the phenomena are independent of the so-called separative power of the glass employed to their detection.

Surprise, nevertheless, has been expressed that the distance between the twin lines should at times be recorded as actually less than the so-called separative power of the instrument. Such surprise would be justified were it founded on a just conception of the capabilities of a glass. But such is not the case. The resolving or separating power of a telescope is not the measure of its *minimum divisibile* as we may perhaps style its power of distinguishing detail.

The so-called separative power of a glass depends upon the spurious disk. Owing to the mode of propagation of light the image made by a telescope of a point is not itself a point but a solid circle of illumination surrounded by concentric rings of light. This image is again affected in a somewhat similar manner by the pin-hole aperture between the ocular and the eye. In both the cause of spreading of the point into an area is the summation of the disturbances of all the little waves from every part of the grand wave-front. The analytical expression for this in the first case is

$$\sin\left\{\frac{2\pi}{\lambda}(vt - B)\right\} 2\, e^2 \int_{-1}^{+1} \sqrt{1-\omega^2}\,.\cos n\omega\,.\,d\omega$$

In order to produce darkness the amount of motion in one direction must be counterbalanced by that in the opposite one; the

particles must be in antagonistic phase. For this to be possible the paths of the rays must differ by half a wave-length and this

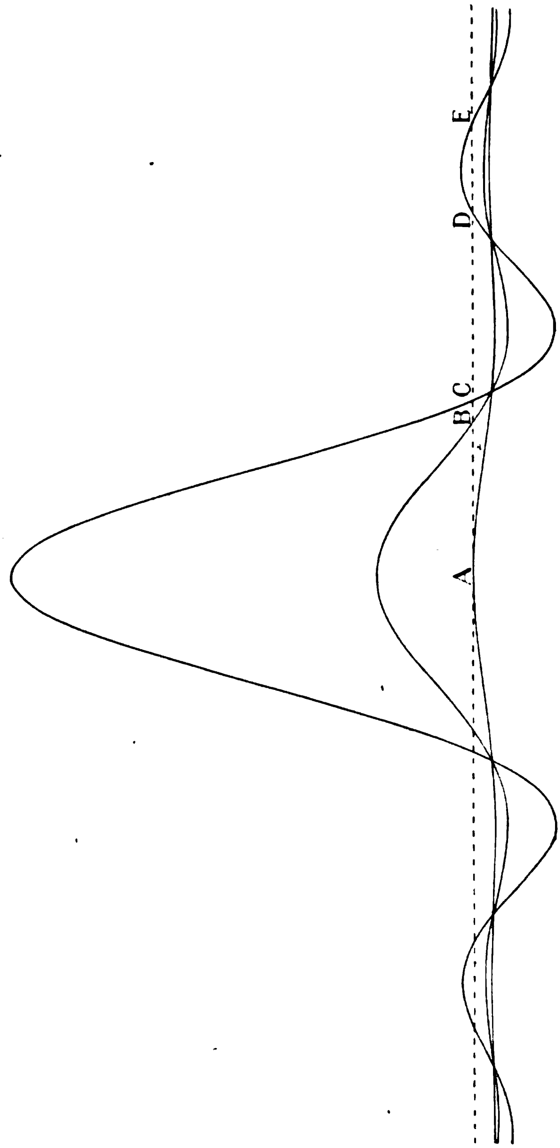


Fig. 1.

can only occur at a certain distance from the centre of the image. It will occur again a little farther out and so it will be repeated to infinity. That we see but a finite number of bright and dark rings is due to insensitiveness in the eye. A certain strength of

illumination is necessary before the retina can take cognizance of the stir.

In order to show the state of things more immediately two diagrams have been prepared from the analytic expression for the amplitude of illumination at any distance from the centre of the image. In Fig. 1 we have the amplitude shown in elevation;

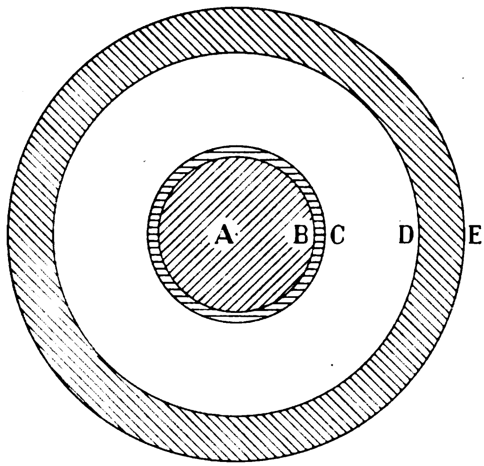


FIG. 2.

in Fig. 2 in plan. The intensity varies as the square of the amplitude.

In Fig. 1 a broken line parallel to the zero line of illumination appears cutting the amplitude curve. This line denotes the amount of illumination necessary to affect the eye. Anything less than this the eye regards as darkness. This line is therefore the zero line in practice. It is the see-level of observation.

According as the point emitting the light be strong of brilliancy or weak, the amplitude curve will rise higher or less high. In the diagram curves are shown for three different intensities. Upon considering these curves we shall be aware of the relatively different physiognomy of each to the eye. The see-level being not at the absolute zero of effect the aspect of the disk and rings is materially modified by the actual intensity of the point.

In the first place it appears that the maximum size of the spurious disk is strictly limited being solely a function of the aperture. But furthermore it appears that the spurious disk may be of any size less than this maximum down to absolute zero. There is therefore no such thing as a definite size of disk for a given aperture. The spurious disk cannot exceed a certain

quantity for a certain aperture but it may fall indefinitely below that amount. It cannot actually reach the zero limit, if it stand alone, because a certain volume of light is necessary to affect the eye; but if it form part of a surface there is no such limitation to its diminutiveness. Because then the retina is roused by the whole effect; just as deaf people hear better amidst much noise.

Now what is known as the separative power of a telescope is the distance between the centres of two contiguous spurious disks. When two star-images are thus presented they are said to be separated. We see, then, that the separative or resolving power of a glass is not an absolute quantity but one dependent upon the brilliancy of the stars concerned. For faint stars it is higher than for bright ones. A glass which will not pull two stars of the third magnitude apart will more than do so for two of the ninth. What is usually given as the resolving power is a sort of mean value approaching, however, the maximum size of disk.

Even with star-points, then, it is possible to separate below what the theory of spurious disks would permit, because the actual disks fail to occupy all the space they might. But in the case of an extended surface like that of a planet division may be carried much closer yet. For the eye can recognize a superficies of a brilliancy far inferior to what would be needed to affect it coming from a point. The Moon may be seen by day while the stars are invisible yet the lustre of the latter vastly exceeds the albedo of the first.

To convince himself practically of the change in size of the spurious disk with difference of brilliancy in the emitting point, one has only to view the reflection of the Sun from the side of a bottle and then diminish the brilliancy of the reflection purposely or let nature do it for him. He will then note the gradual shrinking of the spurious disk and the concomitant widening at its expense of the first dark ring, until from a very sensible expanse it seems hardly more than a point of light.

For the separation of detail upon a planet's disk, then, the so-called separative power of the telescope used becomes a meaningless term. The possible resolution depends not upon the aperture but upon the separative power of the human eye or *minimum visibile* as it is called if the contrast suffice to show the detail at all. How near to its minimum of zero the spurious disk then becomes it is not possible to state · but that it approaches this limit is certain both from theory and practice.

The *minimum visibile*, not the so-called resolving power of the

glass here becomes the essential factor to the *minimum divisibile*. Now the *minimum visible* of the human eye is commonly given as 1′ of arc. In our experiments at Flagstaff we found that this could be lessened and that two lines could be seen apart by glimpses when the distance between them was narrowed to 45″.

It is a curious and suggestive fact that in the human eye the cones should be arranged at just such a distance apart as not to disclose the spurious disk in the normal condition. For the maximum value for the spurious disk for the eye is 46″ which is very near the limit for the *minimum visibile*. This maximum is only attained under very bright lights which was not of course the case at the time of the experiments with the double lines mentioned.

Now in the case of the double canals whose distance apart elicited surprise the eye-piece used was one of 310 diameters. Dividing, then, 1′ by 310 we have for the width of a pair which should be visible, supposing the telescope as good as the naked eye

0.19″ or if we take 45″ as *minimum visibile*

0.15″

That 0.23 of a second should have been detected is, therefore, not in truth surprising, though possibly creditable to the instrument.

PARIS, September 8, 1904.

THE ULTIMATE MEASUREMENT OF GRADUATION ERRORS.

R. H TUCKER.

FOR POPULAR ASTRONOMY.

In Meridian Circles of modern construction, and of the size generally in use, the circles are graduated usually with divisions 2′ apart. The 10′ divisions are commonly longer than the intermediate ones, while the even degree divisions are of still greater length, and are numbered.

The readings of the microscopes are made at the same point in the field of each, often marked by a fixed thread, perpendicular to the divisions, and to the threads actually used in making the readings. Hence no uncertainty in reading should arise from the divisions being of unequal length; and no loss of precision is likely to occur from lack of parallelism between the movable

threads and the divisions, though the former are carefully adjusted, to avoid any such inaccuracy.

The readings are taken, by placing the close pair of movable threads on each side of a division, so that the spaces are as nearly equal as the eye can estimate them. There may be a tendency to estimate one space consistently smaller than the other. This error of estimate, which is systematic in character, is eliminated from any measure of a star's position, and from the measurement of graduation error. For both classes of measure always consist of the difference of a reading upon some set of divisions of the circle, and either another such reading, or the mean of a number of readings. If all readings are subject to the same amount of systematic error, this will not affect the difference.

Except in zone work, which is done with great rapidity, and without aiming at the highest precision, four microscopes are usually read, at each observation. The eccentricity of the circle is eliminated, in effect, from the mean of the four microscopes, placed at points 90° apart. And the probable error of the reading of four microscopes is half that of a single microscope. Since corrections for the errors of graduation are desired, generally, for work of high precision only, the measurement of the graduation error of the mean of four divisions is usually all that is required.

Some account of the process of measuring the graduation errors of the Repsold Meridian Circle, of the Lick Observatory, was given in this publication, last December. Before going into farther detail, the preliminary steps may be reviewed, again.

By means of the movable circle, long arcs of the fixed circle can be measured, with a perfect standard of comparison if the arc measured is an aliquot part of the whole circle. The first step was to measure the 45° arcs. For this purpose each 45° arc of the fixed circle, A, was compared with every 45° arc of the movable circle, B. The sum of the eight 45° arcs of B is a perfect circumference; and the error of any 45° arc of A, which depends upon the mean of the eight arcs of B, or one-eighth of a perfect circumference, has consequently been compared with a perfect standard of angular measure.

The 15° arcs of A have been similarly compared with the 15° arcs of B. Since this subdivision into equal parts forms as long a series of measures as is advisable to make consecutively, another process must be used for smaller arcs.

The 3° arcs were measured by making steps of 9° in length, be-

ginning, for different sets, at 0°. 3°, and 6°. The series first named will include 0° and 45°, which had been already determined. The second will include 30° and 75°, also determined in the 15° series of measures. And the third will include 15° and 60°.

The investigation includes the measurement of the 3° arcs of circle B, also, for the results serve equally well for both circles. Up to the completion of the 15° series, the arcs of each circle have been measured with a perfect standard of comparison. For the 3° arcs, the error of measurement of the respective 15° divisions enters into the error of the result.

This error of measure is an important consideration. It has been remarked that there is a possibility of carrying the measurement of graduation errors too far. This may evidently be true, if corrections are to be applied, which rest upon insufficient measures. In other words, if the probable error of the measure finally becomes too large, in proportion to the error which we desire to correct. The determination of the probable error of measure is therefore desirable, at every step of the investigation.

In the measure of the difference of two divisions, we must include the probable error of the correction adopted for the division used as a base, to obtain a trustworthy value of the uncertainty of the final correction. The inclusion of the probable error of the standard begins, evidently, in the process followed here, at the measurement of the 3° arcs. Each 3° division is measured from two 15° divisions, for which the probable errors of measurement are very small.

The 1° divisions were determined by readings in short sets, extending through three degrees, each set including a 3° division; or, in one set of every three, including two 3° divisions, at beginning and end. The probable error of measurement must be increased by the effect of the probable error of the corrections for the 3° divisions, to obtain the final probable error of determination.

The step down to each 10′ division was treated of, in detail, in the preceding article, mentioned above. From this point the ultimate measures of all the 2′ arcs could be attained by the use of each circle by itself. Leaving the instrument stationary, one could measure from the 10′ divisions to any 2′ division, without using the micrometer microscopes over a greater distance than four minutes, or two revolutions each side of the centre of the field. This distance is commonly used in all observations, where readings are made upon two adjoining divisions, for purposes of

greater precision, and for the determination of the Runs correction. If the method is to be used for measures of graduation errors, the Runs correction must be very precisely determined; for it enters with full effect, and is multiplied by the number of revolutions between the limiting divisions. This method could be employed, where a certain number of divisions are used, in work upon the Fundamental Stars. And as great a precision of measure could be reached, as would be desired, by making a large number of readings at each division. The final precision must always be limited, however, as has been plainly stated, by the precision of the measurement of the 10′ divisions. The measures could be made with great rapidity and convenience, measuring certain divisions with several repetitions, and then going over the same measures at another opportunity; for it is better to vary the conditions, to some extent, and not repeat the same measures a large number of times consecutively.

While measuring any desired division, the determination of all of the divisions, included in ten minutes, could be made conveniently. The instrument could be set so that two 10′ divisions would fall at equal distances, right and left of the centre of the field. This would require the use of the microscope micrometers, for a space of five revolutions, each side of the centre. In comparison with the use of the filar micrometer, for measures of position with an Equatorial, this would not be considered excessive, as regards distance. The field of the microscope is about 50′ of the circle, and the parallax does not appear likely to be of perceptible injurious effect. The effect would operate in full, if it exists; for the division to the left would be displaced in one direction, while that to the right would be displaced in the contrary direction, and both displacements would operate to increase, or diminish, simultaneously, the measurement of the extremities of the arc from the centre of the field. Thus each division, in the ten minutes, would be subject to a distinct amount of systematic error.

The Runs correction, determined by the difference of adjoining 2′ divisions, or from the two extreme divisions, would be systematically too great, or too small, at the extremities, if there be any perceptible effect of parallax. The existence of such an effect can be tested by the readings, if enough of them be made at various settings.

Periodic errors of the screws of the micrometers may be of appreciable effect, in using them over so long an arc. In the regular observations of stars, made here, the practice is to set

the instrument, so that the divisions of the circle fall at nearly the same reading of the microscopes, throughout. This practically eliminates the error of Runs, and the same part of the screw is continually in service. In graduation error measures, the same practice has been followed. This method of measuring ten minutes of arc, between two 10′ divisions, may therefore be subject to some classes of systematic error. Each 2′ division would be measured always from two 10′ divisions in the process, which would be one advantage.

These classes of systematic error, in the measurement of graduation errors over ten minutes, would disappear, if the readings were begun at some one division, and repeated in sets which should begin at the next 2′ division, until the arc desired should be completed under all the varying conditions. Continuing this process, the entire circle could eventually be measured, to the ultimate 2′ divisions.

As an example of such a set of measures, the corrections given below have been determined, for one degree of Circle B. The sets extend from 359° 52′ to 1° 8′; but only the 2′ divisions from 0° to 1° have received the full number of determinations, and the divisions outside these limits are not included in the Table. The telescope was moved 2′, between each set and the following, and readings were taken on six 2′ divisions in a set. Since each division is included in six sets, this process gives in all six measures of each 2′ division, one of which is based upon two 10′ divisions.

The tabulated corrections for the 10′ divisions have been adopted provisionally. They are derived from the mean of 300 measures, and are not likely to be much altered by those yet to be made, during the investigation of the 10′ arcs.

After correcting all the readings, by the quantities given in the first approximation below, each original reading has been compared with the readings upon the other five divisions in each set. This gives the second approximation. The error of measure in the second approximation is considerably reduced, as it is due to the comparison of one reading with the mean of five; as against the comparison of two readings, only, in the first approximation, in every set.

The probable error of measure of the 2′ divisions, in this series, is $\pm$ 0″.070. Since the 10′ divisions of Circle B have been measured with a probable error of less than $\pm$ 0″.01, the error of the base needs hardly to be taken into account in these results.

The probable error of measurement of the 10′ divisions of Circle A will not exceed $\pm$ 0″.07, and, consequently, two of such

divisions being used in the derivation of each 2′ division, the probable error of the last, if measured on this plan, would not be likely to exceed $\pm 0''.09$. By repeating the readings, this could be slightly diminished. Besides the correction for Runs, there is an evident correction required for the original readings, due to periodic error of the screws, amounting to $0''.05$ for one revolution, which has been uniformly applied from one extremity of the ten-minute arcs to the other. Its effect would have been eliminated, in the mean of the results, had it not been applied. No parallax can be detected, in the comparison of the readings; and if such error existed, its effect would be eliminated in the mean results, derived in this process: The precision of reading is slightly diminished, for the outer divisions of the ten-minute arc, as indicated by the comparison of the probable errors of Runs, determined at the centre of the field, and at the extremes; the values being $v = \pm 0''.23$ and $\pm 0''.27$ respectively: mean $\pm 0''.25$. This includes the effect of errors of graduation. The probable error of a circle reading is $\pm 0''.12$.

CORRECTIONS FOR GRADUATION: CIRCLE B. 1904.

°	′	Standard.	First Approx.	Second Approx.	v
°	′	″	″	″	″
0	0	0.00	......	......	− 0.05
	2		+ 0.11	+ 0.14	+ .09
	4		+ .04	+ .08	+ .03
	6		− .03	.00	− .05
	8		− .12	− .09	− .14
	10	+ .01	......	......	− .04
	12		+ .08	+ .08	+ .03
	14		− .35	− .33	− .38
	16		+ .07	− .01	− .06
	18		− .32	− .34	− .39
	20	+ .19	......	......	+ .14
	22		− .46	− .50	− .55
	24		− .15	− .15	− .20
	26		− .24	− .23	− .28
	28		− .22	− .21	− .26
	30	+ .16	......	......	+ .11
	32		+ .18	+ .20	+ .15
	34		− .02	− .05	− .10
	36		+ .18	+ .14	+ .09
	38		+ .06	+ .12	+ .07
	40	+ .18	......	......	+ .13
	42		+ .04	+ .02	− .03
	44		+ .34	+ .37	+ .32
	46		+ .26	+ .28	+ .23
	48		− .01	− .05	− .10
	50	+ .20	......	......	+ .15
	52		+ .28	+ .31	+ .26
	54		+ .32	+ .30	+ .25
	56		+ .33	+ .29	+ .24
	58		+ .52	+ .48	+ .43
1	0	+ .11	......	......	+ .06

The above tabulation exhibits the quality of the graduation.

The last column contains the residuals from a mean correction of $+ 0''.05$. The average error of graduation is found to be $\pm 0''.18$, which is more than twice as large as the error of measurement in this series. The largest graduation error is a little greater than three times the average, and there are four which are twice the average. There is some tendency towards groups of similar sign, and the average error of a two-minute arc is found to be $\pm 0''.20$. The quality of the graduation appears to be the same, for these $2'$ divisions, as for the $1°$ divisions previously measured, for which the corrections are tabulated in Vol. IV of the Publications of this Observatory.

It should be evident that the full investigation of graduation error involves a vast amount of labor; and that it is highly necessary to use methods that eliminate the effect of systematic errors, and avoid the accumulation of accidental error, as far as possible.

LICK OBSERVATORY, University of California,
September 30, 1904.

CULTURE VALUE OF MATHEMATICS AND ASTRONOMY.

WM. W. PAYNE.

From early records in science to the present time, the claim has been made that the study of mathematics has high value as a means of training the intellect. That such opinions have been held quite generally, it is easy to verify from history within the reach of ordinary readers, and from modern books that have been written on scientific subjects in general and mathematical themes in particular.

The study of the elementary mathematics has been pursued so generally and so long for the simple purpose of qualifying persons for business or professional life, that the culture side of these studies has been overlooked or neglected in a very considerable degree. It is hard to believe that eminent teachers in the past have not thought of, or have not known of, the culture value, of a high order, that is found in the studies of arithmetic, algebra and geometry. It seems more probable that they have known something of this important fact, but they could not make use of it in any satisfactory way because of untoward circumstances in the past that will readily occur to any thoughtful person.

If we bring this matter down to the present time, and apply it to much of the study and training in the higher mathematics, commonly found in colleges, universities and technical schools,

the same thing is most disappointingly apparent. The query naturally arises, why is this so? Is the plan of this mutual training all wrong that the highest and best in it should not be gained? Certainly not. Modern courses of study for intellectual discipline are pliant and logically strong. But the idea that seems to prevail in the minds of those who have had the responsibility of forming them is, that the discipline to be gained will give almost certain advantage in seeking place and profit in after life. This aim is set before the student constantly and urgently for the purpose of enlisting interest and effort to secure scholarly attainments. If mature scholars in science hold such ideas, and advocate them only, or chiefly, from such a view of the real value of knowledge, it is certain that young people who want such advantages in life will think of scholarship and its true worth in about the same way, and willingly pay the tremendous cost of it when actuated by such a motive as that. In doing so they rightly infer that because men have become eminent in that way, others may do so, and that is sufficient. They do not enough concern themselves about the ways and means to the end they ought to desire, especially that which springs from a higher and a more noble motive, possibly, either not knowing or not realizing that there is a more excellent way to obtain a more excellent thing of the same kind as that which they earnestly covet.

It is our purpose in what follows to call attention to some points that will show clearly and precisely what we mean by the high culture possible from mathematical studies.

From the earliest records we have, it is inferred that the Egyptians had gained a rude knowledge of numbers and of geometry, because they had constant use for such knowledge to meet the practical ends in life which it would immediately serve. If it shall appear later that the Chinese had this knowledge before the Egyptians, or, if modern antiquarian research shall reveal the fact that other Eastern peoples had gained this knowledge at a much earlier period, it is certainly probable that all must have acquired it essentially in the same way, whatever may have been the particular methods.

The same thing must be said of the Phoenicians whether they were discoverers of the knowledge of which we are speaking or, were chiefly copyists from other sources, as we know was true of the Babylonians at a later time.

The main point in these references is the need that was felt for such knowledge to do ordinary business. It was not sought for its own sake, nor because the things were or were not, essentially

true in themselves, but because they were useful in dealing with the events of daily, practical life.

On the other hand when a scholar begins to prove a theory and weigh its truth for its own sake, he has reached a higher plane of mental activity than that which he occupied when seeking merely its results for detailed uses in practical affairs. The reason why this is so is perfectly plain. The scholar who works in this higher plane of thinking must use his mental powers logically and severely; he must work as profoundly as he possibly can, in order to find the relation of fact, old and new, that may constitute a law in nature, or, may measure, justly and truly, motives to human action. In other words the question is what will most aid a person to a large insight into mental conditions and mental resources to make for him a ruling motive which should act manifestly in all the course of his intellectual development. If mathematical studies furnish such conditions and resources, wholly or in part, then those studies should be pursued always with that end distinctly in view. There can be no question but that mathematics is a body of exact truth which is the foundation of all science. Such truth is the source of large and healthful, mental growth and its power in the intellect is a constant witness to right action that furnishes the best and highest conditions for mental endeavor possible.

If we turn to the history of great mathematicians, in early times, among the Greeks, and notice how they studied and what they accomplished, we will certainly find some evidence to bear on this question, especially if we believe they reached a distinction in scholarship, in their time, that should entitle them to the rank of cultured scholars.

In the sixth century before Christ, it was apparently little more than an accident of travel, as a merchant, that brought Thales into Egypt, where during his leisure he studied philosophy and science. Afterwards he went back to his old home in Miletus and there he founded the great Ionian school, the first of the Greek schools of mathematics with a definite history. Thales became one of the seven sages of Greece, and we wonder how it was that he came to receive such high honor at the hands of his own people. We know that he was naturally shrewd, but his shrewdness did not exalt him. History says he predicted the total solar eclipse of May 28, 585 B. C., and on account of that he became very famous. The fact that a man could predict a total eclipse of the Sun, at that time, would be something wonderful in the eyes of the common people, but it would not be enough to give

such high and enduring rank among the cultured and ruling classes of the Greeks. To say the least, it is improbable that this explanation is the true one, because the Egyptians could certainly predict eclipses before the time of Thales, and it is very probable that he knew their methods, especially if Herodotus is right in saying that he was of Phœnician descent; because the Phœnicians had close relations with the Babylonians and other Eastern peoples in trade, and the mathematical knowledge then known to any must have been common property to all in some degree.

If then we have not found the real basis of the greatness of Thales in what has been said, it is needful to ask wherein did it lie? It seems more probable to the writer that it was due to the training that he himself received in Egypt and in his own school at Miletus, and the way he secured it. He gave up his business; he devoted his whole time to it, after a start was made and he put his whole life into it, as a thing worthy of such a costly outlay for him. He could not do more; and the motive in t all seems to have been a noble one, and the result was splendid in achievement.

Pythagoras is another illustration. His life was one of supreme devotion to discovery in pure geometry, and to the study of number, and all his philosophy had its foundation in mathematics. He was a man of power because of his pure life and his severe self-discipline for the sake of intellectual gain. He was a great scholar, in his times, because he diligently searched for new truth for its own sake, and for the advantage of the Pythagorean school of mathematics which he had founded and which grew to be a ruling power in the government of colonies where it flourished. He is an example of what right training in mathematical studies can do to secure for a man the power of a cultured mind, that will give him place and influence in life in the right way, and without depending on barter and sale, as a huckster does on the street corners of a great city.

A still more striking example of the right way of coming into a life of cultured power is that of Sir Isaac Newton, who was the ablest scholar in mathematics that has ever lived. The most sententious saying about him that has come under our notice, is that by Bishop Burnet when speaking of his religious and conscientious character. He said Newton's was the "whitest soul" that ever lived. Such a claim, if true, would be of fundamental worth as a basis for large achievement.

Newton had also a keen intellect in wonderful balance of

mental powers. He worked modestly, but incessantly. He had unique power in concentration and abstraction, so that he would often become wholly unconscious of what was going on around him, except the one thing that occupied his mind at the time. He was always scrupulously just, and even generous enough to say that his own discoveries in mathematics were due to the admirable work done by his predecessors. When such a rare cómbination of fine qualities of mind meet in one man, it is not a wonder that such an intellect will make great victories over nature, while itself grows charmingly beautiful in its symmetry of action and its exquisite finish of thinking power. This is what we mean by a cultured mind.

There is much more to be said about the culture value of mathematical studies, but we can go no further now. There is also a broad and most fruitful field in general astronomy bearing on this same topic, in effective way, that must wait for another opportunity.

REDUCTION OF 295 PHOTOGRAPHS OF EROS MADE AT NINE OBSERVATORIES DURING THE PERIOD 1900 NOVEMBER 7-15, WITH A DETERMINATION OF THE SOLAR PARALLAX.* II.

ARTHUR R. HINKS, M. A.

§ *Adopted Weights of the Different Series.*—We have now to adopt a system of weights for the different series of plates, taking into account both the tendency towards systematic error revealed in some of them and also the general character of the plates as indicated by the average size of the comparison star residuals upon them. The average residuals are:—

	In X. ″	In Y. ″	Adopted Weight.
Algiers	0.16	0.12	⅔
Cambridge	0.11	0.10	1
Lick	0.10	0.12	1
Minneapolis	0.21	0.20	0
Northfield	0.18	0.17	¼
Oxford	0.17	0.17	⅔
Paris	0.10	0.11	1
Tacubaya	0.28	0.19	1/10

The eleven Cambridge plates on which guiding error was found have been given weight ⅔.

Part of the average residual is due to errors in the adopted

* *Monthly Notices*, June, 1904.

places of the stars, whose probable error is less than 0″.04. And it will be shown later that the connection between the average star residual on the plate and the final residual in the equations of condition is not so close as might have been expected. After consideration of all the circumstances I have adopted the weights given in the last column of the above table.

§ 13. *Summary of Observations used.*—

Algiers.

40 plates were measured and communicated.

1 was rejected for large discordance, evident in original measures.

8 were rejected for want of central stars.

31 were used.

Cambridge.

110 plates were measured.

5 were rejected for various reasons—wrong time record, clouds during part of exposure, or large discordances for images marked "probably defective" during measurement.

1 was ommitted by mistake.

104 were used.

Lick.

28 were measured, and all were used.

Northfield.

23 were measured.

2 were rejected for clouds during exposure.

21 were used.

Oxford.

55 were measured.

25 were too late to be included.

30 were used.

Paris.

21 were measured and all were used.

Tacubaya.

15 were measured.

1 was rejected for large discordance.

14 were used.

The 9 San Fernando and 21 Minneapolis were not included, for reasons given above.

§ 14. *Construction of the Plate Ephemeris.*—A special "plate ephemeris" for my standard centre was constructed in the way described in my second paper (*Monthly Notices*, lxii. 1902, p. 554, §6), to give standard co-ordinates of the places of the planet

at the times light left it, as seen from the Earth at successive Berlin midnights when the light arrived. It was based on the separate heliocentric ephemerides in ecliptic rectangular co-ordinates of the Earth and of *Eros*, published by M. Lœwy in *Paris Circular*, No. 8.

These ephemerides have been computed with 8-figure tables, and are given to eight places of decimals. The third differences do not run quite smoothly in either, and I have found it possible to improve them by making small alterations not exceeding three units in the last place of decimals. In the case of the heliocentric ephemeris of *Eros* this is perfectly simple. But in so treating the ephemeris of the Earth one must be careful not to smooth out any part of the real inequality due to the lunar equation. In order to avoid this the third differences in the Earth ephemeris were plotted against the time. The character of the real periodicity in the differences due to the Moon was then quite conspicuous, and all that was done was to make such slight alterations in the last place of decimals as would remove roughnesses without modifying in the least the character of the curves.

Plate Ephemeris of Eros

for Standard Centre α 1^h 57^m 8^s.0. δ + 54° 22′ 0″ (1900.0).

Berlin, Midnight. 1900.	ξ_0	η_0	Berlin. Midnight. 1900.	ξ_0	η_0
Nov. 5	+ 25.23477	− 1.95306	Nov. 12	− 11.30440	− 1.74989
" 6	+ 19.98262	− 1.15023	" 13	− 16.38109	− 2.77464
" 7	+ 14.72449	− 0.60057	" 14	− 21.38732	− 4.06752
" 8	+ 9.46989	− 0.30717	" 15	− 26.31072	− 5.62885
" 9	+ 4.22892	− 0.27297	" 16	− 31.13868	− 7.45847
" 10	− 0.98781	− 0.50062	" 17	− 35.85846	− 9.55570
" 11	− 6.16937	− 0.99235			

There seems to be no doubt that this ephemeris is free from accidental roughness to a nicety well within what our observations will demand; and I must repeat the expression of my acknowledgements to M. Lœwy for his kindness in providing the separate heliocentric ephemerides with which it was constructed.

It may be noted here that there was an error in the computation of the plate ephemeris used in my second paper. The terms expressing the small heliocentric latitude of the Earth were taken with the wrong sign, which accounts for a peculiarity of the solution given in *Monthly Notices*, lxii. p. 559.

§ 15. *Interpolation from the Plate Ephemeris and Calculation of Parallax Factors.*—It is a decided advantage of the plate ephemeris that the third differences multiplied by the interpolation coefficients are small and the fourth negligible. It is also

most convenient to have the ephemeris expressed in terms of a single quantity, the adopted unit, instead of in hours, minutes, and seconds of time, and degrees, minutes, and seconds of arc; the labor of computation is thereby much reduced.

The geocentric co-ordinates of the observatories at the epochs of observation were calculated according to the formulæ given in *Monthly Notices*, lxii. p. 30. (But see below.) But it should have been remarked there that it is proper to use the *apparent* R. A. and Dec. of the standard centre, viz. $1^h\ 57^m\ 15^s$, $+54°\ 22'.5$, in calculating those co-ordinates.

In computing the Lick co-ordinates the altitude of the observatory was taken into account.

The parallactic displacements of the planet were calculated with an assumed value of the solar parallax $\pi = 8''.800$.

[It may be noted here that there is an error in my first experimental paper (*Monthly Notices*, lxii. pp. 30 and 31). The equations at the bottom of p. 30 should be printed

$$\xi = \frac{X}{Z} = \frac{I}{N}\left\{ L - \left(a - \frac{cL}{N}\right)\pi \right\} = \nu \left\{ L - (a - c\xi_0)\pi \right\}$$

$$\eta = \frac{Y}{Z} = \frac{I}{N}\left\{ M - \left(l - \frac{cM}{N}\right)\pi \right\} = \nu \left\{ M - (b - c\eta_0)\pi \right\}$$

and throughout the following page the quantities printed $\nu\,(a - c\nu)$ and $\nu\,(b - c\nu)$ should read $\nu\,(a - c\xi_0)$ and $\nu\,(b - c\eta_0)$. The mistake arose in preparing the paper for press; the right formulæ were used in the calculations.]

§ 16. *Formation of the Equations of Condition.*—On comparing the observed places of the planet with the ephemeris it was evident that the correction to the x ephemeris was nearly constant throughout, and that the correction to the y ephemeris varied slightly with the time. There were no indications of terms depending on squares and higher powers of the time. Of course it will be necessary to make a careful search for such terms; but what would be, from the parallax point of view, a good deal more important would be the existence of a short period variation in the place of the planet related to the light variation. This could be detected most conveniently in the residuals from a preliminary solution. I therefore adopted as my first equations of condition a simple form with only three unknowns in each, $\Delta_1\xi_0$ or $\Delta_1\eta_0$, constant corrections to the plate ephemeris, $\Delta_2\xi_0$ or $\Delta_2\eta_0$ the variation of these corrections per day, and $\Delta\pi$ the correction to the assumed parallax.

The equations expressing the comparison between observation

and ephemeris have the form

$$\xi_0 + \Delta_1\xi_0 + t\,.\,\Delta_2\xi_0 - (\pi + \Delta\pi)\ \ (a - c\xi_0)/\mathrm{N} = x$$
$$\eta_0 + \Delta_1\eta_0 + t\,.\,\Delta_2\eta_0 - (\pi + \Delta\pi)\ \ (b - c\eta_0)/\mathrm{N} = y.$$

Hence, putting

$$\xi_0 - \pi(a - c\xi_0)/\mathrm{N} - x = m'$$
$$\eta_0 - \pi(b - c\eta_0)/\mathrm{N} - \eta = n',$$

we have as the form of our equations of condition

$$\Delta_1\xi_0 + t\,.\,\Delta_2\xi_0 - (a - c\xi_0)/\mathrm{N}\,.\,\Delta\pi + m' = 0$$
$$\Delta_1\xi_0 + t\,.\,\Delta_2\eta_0 = (b - c\eta_0)/\mathrm{N}\,.\,\Delta\pi + n' = 0.$$

Working in units of the fifth place of decimals (that is, in hundred-millionths of the radius of projection), we have on the average

$$m' = +1090$$
$$n' = -\ \ 120,$$

and we shall take as the numerical terms in our equations of condition

$$m = m' - 1090$$
$$n = n' +\ \ 120.$$

§ 17. *Normal Equations.*—The normal equations derived from the measures of each observatory are as follows: the coefficients of $\Delta_1\eta_0$ and $\Delta_2\eta_0$ are the same as those of $\Delta_1\xi_0$ and $\Delta_2\xi_0$, and are not repeated:—

Algiers (*with weight* ⅔).

$20.67\Delta_1\xi_0$	$+\ 48.00\Delta_2\xi_0$	$+\ 1.05\Delta\pi$	$-\ 23 = 0$	$-\ 1.80\Delta\pi$	$+\ 191 = 0$
	$+\ 144.9460$	$+\ 1.1289$	$+\ 24.00$	$-\ 1.9751$	$+\ 1541.67$
		$+\ 64.8469$	$+\ 502.17$	$-\ 7.2655$	$-\ 138.14$

Cambridge (209-252).

39	$-\ 86.62$	$+\ 14.77$	$+\ 143$	$-\ 22.73$	$-\ 3554$
	$+\ 203.9652$	$+\ 34.6727$	$-\ 648.74$	$+\ 52.9410$	$+\ 8341.17$
		$+\ 69.5633$	$-\ 265.00$	$+\ 19.5289$	$+\ 2189.68$

Cambridge (254-265, *with weight* ⅔).

7.33	$-\ 8.68$	$+\ 10.13$	$-\ 86$	$+\ 4.09$	$-\ 162$
	$+\ 10.2813$	$-\ 12.0257$	$+\ 106.15$	$+\ 4.8973$	$+\ 212.92$
		$+\ 14.1997$	$-\ 134.35$	$+\ 2.6597$	$+\ 135.04$

Cambridge (266-335).

54	$+\ 64.36$	$-\ 15.03$	-1294	$-\ 21.64$	$+\ 896$
	$+\ 320.3484$	$+\ 52.4368$	-2041.52	$-\ 27.6246$	$+\ 7266.53$
		$+\ 78.3565$	$-\ 482.45$	$+\ 16.6724$	$-\ 347.92$

Lick.

28	$+\ 8.60$	$+\ 25.63$	$+\ 614$	$+\ 5.40$	$-\ 553$
	$+\ 91.7948$	$+\ 5.7855$	$+\ 676.45$	$+\ 6.1198$	$+\ 3376.39$
		$+\ 63.2493$	$+1047.91$	$-\ 7.5570$	$+\ 15.22$

Northfield (*with weight* ¼).

5.25	+ 4.69	+ 5.09	− 180	− 0.47	+ 114
	+ 53.8704	+ 7.4601	− 283.77	− 4.7879	+ 1550.90
		+ 9.6121	− 238.79	+ 1.1716	− 26.30

Oxford (*with weight* ⅔).

20	+ 1.19	− 4.25	− 691	− 20.14	− 377
	+ 111.9618	+ 41.7571	− 353.11	+ 11.2237	+ 2924.95
		+ 46.1206	− 375.12	+ 24.8782	+ 805.81

Paris.

21	− 25.19	+ 7.28	− 229	− 3.73	− 561
	+ 202.3461	− 46.8666	+ 666.11	+ 0.1252	+ 3416.05
		+ 24.7698	+ 84.97	+ 7.1409	+ 166.38

Tacubaya (*with weight* $^1/_{10}$).

1.40	+ 2.44	+ 0.35	+ 11	+ 1.35	+ 107
	+ 13.7509	− 2.2404	+ 541.80	+ 1.8865	+ 674.97
		+ 3.7134	− 94.33	+ 1.8564	+ 134.49

The normal equations for the combined solution are, therefore:—

$+196.65\Delta_1\xi_0$	$+\ 8.79\Delta_2\xi_0$	$+\ 15.48\Delta\pi$	$-1207.00=0$	$-67.75\Delta\pi$	$-\ 3899=0$
	$+1153.26$	$+\ 82.11$	-1312.63	$+42.81$	-29305.55
		$+\ 374.43$	$+\ 45.01$	$+88.73$	$-\ 2934.26$

And the solution is: From the x equations:—

	Weight.
$\Delta_1\xi_0 = +\ 6.136$	196
$\Delta_2\xi_0 = +\ 1.136$	1135
$\Delta\pi\ = -\ 0.623$	368

From the y equations:—

$\Delta_1\eta_0 = +\ 18.688$	143
$\Delta_2\eta_0 = -\ 25.309$	1121
$\Delta\pi\ = -\ \ 6.589$	54

§ 18. *Relative Weights from the Residuals.*—The following table gives the average residual in an equation of condition weighted according to the scheme given above.

	Weight Adopted.	Average Residual. X Equations.	Y Equations.	No. of Equations.
		″	″	
Algiers	⅔	0.109	0.111	31
Cambridge (209-252)	1	.152	.129	39
" (254-265)	⅔	.132	.080	11
" (266-335)	1	.105	.087	54
Lick	1	.101	.093	28
Northfield	¼	.111	.134	21
Oxford	⅔	.134	.105	30
Paris	1	.093	.099	21
Tacubaya	$^1/_{10}$	.128	.103	14

The result shows that some improvement might perhaps be effected by further weighting. The first Cambridge series is not good and should have less weight; so also should the Oxford

series; while Paris should have had more weight. This is on the assumption that the residuals are accidently disturbed, which I shall show is not the case. It follows that the above average residuals are not necessarily proportional to the true weights, but they may be taken as showing that the system of weights adopted did not differ widely from the truth. We shall not improve matters by making a fresh solution with revised weights before we have considered the systematic deviations of each series from the mean.

§ 19. *Systematic Deviations of each Series from the Mean.*— In the first column of the following table we have the mean residual (taking account of signs) in the equations of condition from each series of plates:—

	Mean Residual.		Parallax Factors in X.	
	In X.	In Y.	Numerical Sum.	Algebraic Sum.
	″	″		
Algiers	+ 0.013	− 0.050	41	+ 1
Cambridge (209-252)	+ .016	+ .004	50	− 15
" (254-265)	− .013		12	+ 12
" (266-335)	− .033		58	− 14
Lick	+ .057	− .021	34	+ 26
Northfield	− .028	+ .019	13	+ 10
Oxford	− .047	+ .009	37	− 5
Paris	+ .039	+ .048	18	+ 7
Tacubaya	+ .011	+ .029	6	+ 1

Taking the probable error of an X equation of condition as $\pm 0''.10$, we see that the third Cambridge series, the Lick and Oxford, and perhaps the Paris series have mean residuals considerably larger than might be expected if they were fortuitous; there is an appearance of systematic divergence from the general mean. It becomes important to see whether this may have affected prejudicially the value found for the parallax. The fourth and fifth columns contain the numerical and algebraical sums of the parallax factors in the X equations of condition. They show whether in any series parallax factors of one sign have predominated. Further, since similarity of sign in the corresponding quantities of the second and fifth columns shows a tendency to diminish the deduced value of the parallax, we are able to judge from this table in what direction a systematic error will have acted.

The most conspicuous case of want of balance in the parallax factors is found in the Lick series (where evening plates were deliberately selected to coincide in time with morning plates of the eastern hemisphere). If the Lick residuals are really systematic this series will have tended to reduce the value of the parallax. A similar, though very much smaller, effect may have

been produced by systematic error in the third Cambridge series, the Oxford and Paris series.

We may conclude that if these systematic discordances are real, and have produced any sensible effect, they have probably tended to make the parallax too small rather than too large. I am disposed myself to think that there is some reality in them, and that we cannot say that the results of a series of photographs made with different instruments are really homogeneous, though they have been reduced to the same system of carefully determined stars. If this is really the case it is hardly necessary to point out the futility of supposing that the most accurate results can be obtained by combining simultaneous observations at widely separated stations, especially if somewhat different systems of star places have been used.

When the values of the unknowns derived from this solution are substituted in the equations of condition given by the Minneapolis results we have the following results:—

	Mean Residual. in X.	Mean Residual. in Y.	Average Residual. in X.	Average Residual. in Y.
	″	″	″	″
For the 10 single exposures	+ 0.212	+ 0.006	0.216	0.165
" 11 multiple "	− 0.247	+ 0.035	0.389	0.173

These show that the weight of one of the components of a multiple exposure is only about one-quarter of that of a single exposure. But, further, we have the curious result that the single exposures give uniformly large positive residuals, while those from the multiple exposures are strongly negative. I think that this anomaly adds weight to the reasons which compelled us to decide that it is unsafe to use the Minneapolis measures until they have been examined further.

§ 20. *Search for Effect of Planet's Motion.*—It did not seem impossible *a priori* that the planet's motion might have some effect in displacing the mean centre of its image. I therefore took the Cambridge plates in two fashions, guiding upon planet and stars alternately. I have separated the equations belonging to the two series and analyzed their X residuals. The differences are very small, and there is nothing to show that they are other than accidental. It may be concluded that the effect of the trail of the planet, if any, is uniform throughout, and there is no systematic difference between plates following stars and following planet.

§ 21. *Search for Correction to Ephemeris depending on the Square of the Time.*—In order to discover whether the ephemeris requires correction by a term depending on the square of the

time, the residuals were distributed into sixteen half-day groups. The following table gives the number of residuals in successive groups, and the means of the residuals in the X and Y equations:—

Group.	Number.	Mean Residuals. X Equations.	Mean Residuals. Y Equations.
		″	″
1	20	+ 0.006	+ 0.019
2	4	+ .027	+ .179
3	4	− .062	− .052
4	12	+ .002	− .076
5	32	+ .016	− .025
6	23	− .025	+ .052
7	37	− .027	+ .010
8	3	+ .060	− .082
9	1	− .019	− .115
10	8	+ .004	− .089
11	9	+ .006	+ .035
12	15	+ .025	− .056
13	22	+ .041	+ .012
14	2	+ .051	− .072
15	18	+ .023	+ .006
16	39	− .029	.000

There is no evidence here of any sensible term depending on the square of the time. Only two or three of the above quantities are larger than twice what would be their probable value if they were fortuitous.

§ 22. *Search for an Inequality in the Motion of the Planet with the Period of its Light Variation.*—According to André (*A. N.* No. 3698) the variation of light of the planet has a period of $5^h\ 16^m$, during which there are two equal maxima and two slightly unequal minima. If we divide the nine days over which our observations extend into intervals of $5^h\ 16^m$, subdivide them again each into eight parts, and group together the residuals from observations whose epochs fall into corresponding eighths, we have the following result:—

X *Equations. No. of Residuals and Mean for Each Group.*

I.		II.		III.		IV.	
31	$+0''.030$	26	$+0''.023$	55	$-0''.025$	24	$-0''.005$
V.		**VI.**		**VII.**		**VIII.**	
25	$+0''.048$	25	$+0''.012$	21	$-0''.060$	28	$-0''.030$

These figures show no periodicity in 5½ hours. But if we add together groups I. and V., and so on, we have

I. V.		II. VI.		III. VII.		IV. VIII.	
56	$+0''.038$	51	$+0''.017$	76	$-0''.034$	52	$-0''.020$,

which seems to show an oscillation of the planet in the half-period of 2¾ hours.

Before discussing the probability that this is real let us examine

the Y residuals in the same way.

Y *Equations.*

I. V.	II. VI.	III. VII.	IV. VIII.
$-0'.006$	$-0''.002$	$+0''.001$	$+0''.026$
-0.062	$+0.007$	$+0.011$	$+0.001$

Again, there is no evidence of a 5¼-hour period. Taking means of I. and V., &c., as before, we have

I. V.	II. VI.	III. VII.	IV. VIII.
$-0''.034$	$+0''.002$	$+0''.004$	$+0''.013$

which does not suggest any periodicity of the Y residual in the half-period.

If these means are accidental their probable values are about $\pm 0''.013$ in X and $\pm 0''.012$ in Y. It seems to me that we may consider the Y means accidental; only one is larger than might be expected, and that depends upon an abnormally large result in group V., quite unsupported by group I.

The case of the X residuals is different. All four are greater than their probable values if accidental; two are more than twice as great; the two half-series give very much the same effect independently, and the balance of groups in opposite phases of the apparent periodicity is remarkably good.

The reality of the period is, moreover, confirmed by the discussion of residuals from an earlier solution, from somewhat different material, differently weighted, and starting from a different zero of time. These give an apparent periodicity of very nearly the same amplitude and phase.

It is easy to show that the apparent periodicity cannot be due to a chance arrangement of systematically discordant results from one or more observatories. The number of residuals contributed to the four groups is as follows:

	I. V.	II. VI.	III. VII.	IV. VIII.
Algiers	11	6	10	4
Cambridge	24	20	29	31
Lick	5	8	6	9
Northfield	3	2	16	0
Oxford	8	10	8	4
Paris	5	5	7	4

I am inclined, therefore, to think that this result is real, and that the planet has a real oscillation in its X co-ordinates, with a period of about $2^h\ 38^m$ and a semi-amplitude of between $0''.03$ and $0''.04$.

Variations in light could be produced either by irregularity in form or of surface albedo; and either of these could also produce an oscillation in the apparent position of the planet. It is pos-

sible to invent arrangements of figure and albedo which could produce between them almost any desired variation of light or oscillation of centre, in either the period of rotation or half that period. But in general irregularities of figure alone will make the period of the principal oscillation of position twice that of the principal variation in light; while irregularities of albedo will make the two periods the same. In the absence of evidence as to the range and phase of the light variation, if any at the date for which the apparent oscillation in position is found, it is premature to draw any conclusions at present. I am indebted to Mr. H. M. Russell for these remarks.

If the discordances in X given in § 19 are all really systematic they cannot, with the above grouping, produce an inequality with a total amplitude of 0″.001; neither can the inequality, if real, have produced the apparent systematic discordances, except perhaps in the case of Northfield, whose plates nearly all chance to fall in group III.

It remains to be seen whether the inequality in X can have produced a sensible effect on the value of the parallax. If we take the algebraic sums of the parallax factors in groups of equations of condition formed as before we have

I. V. $+3$ II. VI. 13 III. VII. $+27$ IV. VIII. -18.

The average residuals in these groups are respectively

Large + *ve* Small + *ve* Large — *ve* Small — *ve*.

The first has practically no effect; the second and fourth show a tendency to diminish the parallax, which is balanced by the tendency of the third to increase it. We may conclude that the periodic inequality in X has had very little if any effect upon the parallax derived from the present discussion. But it should be noted that, since nine periods are nearly equal to one day, it might affect very seriously a set of plates taken at nearly the same time on several successive days.

§ 23. *Results of the Solution.*—Having shown that there is no sensible term depending on t^2 to be included in our equations of condition, that the assumed weights were fairly correct, that there are no very serious discordances between the results of different observatories, and that the periodic inequality in X which seems to exist cannot affect the parallax to any extent, we may take our first solution as definitive and set out the following results:—

P. E. of one equation of condition of weight unity:—

In X $\pm$ 0″.100. In Y $\pm$ 0″.090.

From the X equations:—

$\Delta_1\xi_0$, constant correction to the ephemeris

$$= [-2''.245] + 0''.0126 \pm 0''.0071$$

$\Delta_2\xi_0$, correction varying with the time per day

$$= +0''.0023 \pm 0''.0030$$

$\Delta\pi$, correction to the adopted value of the solar parallax

$$= -0''.0013 \pm 0''.0052.$$

From the Y equations:—

$\Delta_1\eta_0$, constant correction to the ephemeris

$$= [+0''.247] + 0''.0385 \pm 0''.0077$$

$\Delta_2\eta_0$, correction varying with the time per day

$$= -0''.0522 \pm 0''.0028$$

$\Delta\pi$, correction to the adopted value of the solar parallax

$$= -0''.0136 \pm 0''.0116.$$

Combining the two values of $\Delta\pi$ according to their weights we have

From the X equations	$368\Delta\pi$	$= -0''.4784$
" " Y "	$77\Delta\pi$	$= -1\ .0472$
	$445\Delta\pi$	$= -1''.5256$

whence $\Delta\pi = -0''.0034 \pm 0''.0047.$

And since the value of the solar parallax assumed in the computations was $8''.80$, we have as the result of this discussion

$$\pi = 8''.7966 \pm 0''.0047.$$

Conclusion.

§ 24. This value of the solar parallax has no kind of claim to be called definitive. But it has just succeeded in fulfilling the lesser of the two purposes with which this piece of work was undertaken—to derive from the photographs of *Eros* a value of the solar parallax with a probable error as small as that of the value found by Sir David Gill from his heliometer observations of minor planets, viz. $8''.802 \pm 0''.005$. The two values agree within the limits of their respective probable errors, and perhaps inspire the hope that a final discussion of all the photographs of *Eros* may set the directly observed value of the solar parallax upon so secure a basis that the indirect methods will be compelled to show cause for their discordance.

§ 25. Inasmuch as the principal object of this work was to discover what would happen when one tried to combine the results of a number of observatories into one solution, we may sum up very briefly the outcome of the experiment as follows:

The labor of forming the system of standard stars of considerable relative accuracy found its reward in the facility with which systematic errors were discovered. So soon as confidence in the accuracy of the system was established, the appearance of large residuals became the signal for a search after systematic error; and the search was not often in vain. If the error was found to increase rapidly from the centre, and the outer stars had to be rejected, there were generally enough standard stars near the centre to give a good solution. If the error proved to be guiding error, and the brighter stars were rejected, there remained enough stars of magnitude nearly equal to that of the planet. In fact the treatment of diverse material demands that the standard stars should be fainter, and more evenly distributed close to the planet's path, than are the *repère* stars. And one can hardly overestimate the advantages that arose from the perfect simplicity of the linear reductions in rectangular coordinates.

The finding of occasional guiding error is satisfactory, if only because it was quite certain *a priori* that it must from time to time occur. The absence of any evidence of hour-angle error is the more satisfactory, because that error might reasonably be feared. The discovery that the field of the Crossley reflector becomes useless immediately outside the limit of sensibly perfect definition leaves it still unexplained why the error should take the particular form that it does; while the quite unexpected large errors in the Algiers plates, taken with a refractor of standard pattern, cannot fail to inspire many stimulating doubts as to the absolute value of results obtained with one instrument alone. At the same time the elimination of the larger part of the systematic errors, which seems to have been achieved, assures us at once of the practicability of making a general solution, and of the difficulty of treating the results of any one observatory apart from the others.

The force of the latter couclusion is increased if any one may accept the reality of the oscillation in the position of the planet of short period and semi-amplitude about $0''.03$. This oscillation might well be entangled with the parallax displacements in a quite considerable series of observations made at a single observatory; it is completely separated from the parallax when a general solution is made; and the search for it throughout the period of observation of the planet will make a beautiful test of the real delicacy of our results.

It seems that we may draw, from the experience gained in the

work of the present paper, the conclusion that future work would be greatly facilitated by the adoption of a close system of standard stars. The formation of the system that I have used made a considerable part of the whole labor. But in future the task will be very much lightened, because it will be possible to make the star system depend upon the very extensive series of star places derived from the work of the four French observatories. If we have a standard system whose relative places are known with a probable error of a few hundredths of a second we can get as much accuracy as an individual plate is capable of giving by measuring the planet and eight or ten of these stars well distributed around it. With such a standard system we can discover systematic errors, provided that the residuals in the reduction of the stars are open to inspection; but if any such error is found, it is of the greatest advantage to have at hand the original measured co-ordinates. It is doubtful whether those observatories whose aim is to contribute their results in the form most convenient for a general reduction of all the material could do better than publish simply the original measures. It will probably pay better to give the man who undertakes a general solution the means to carry out reduction *ab initio*, rather than to do any part of it before publication, for the discovery of some systematic error when the observations are combined with others will often necessitate a new reduction.

Finally, if we are able to admit that these conclusions are sound, we are led to the proposition that any observatory with photographs of *Eros* still unmeasured can make its contribution to the definitive determination of the solar parallax of greatest effect by agreeing to select its stars from a close standard system, and doing as speedily as possible the absolute minimum of work. It is the hope of the writer that he may be allowed to submit, in the near future, a selection of standard stars for consideration.

§ 26. I must acknowledge with gratitude the most efficient help which has been given me by Miss Julia Bell, of Girton College, and Miss Anne Malden, of Newnham College, and must thank the Committee administering the Government Grant Fund of the Royal Society for the means of securing this help, without which the work could not have been done at Cambridge.

ON THE SPECTRUM OF NOVA PERSEI AND THE STRUCTURE OF ITS BANDS, AS PHOTOGRAPHED AT GLASGOW.*

L. BECKER, PH. D.†

The spectrum of the new star in Perseus, which Dr. Anderson, of Edinburgh, discovered 1901 February 21, was photographed at the Glasgow Observatory from 1901 March 3 till 1903 January. From the early photographs one gains the impression that the spectrum consists of a number of bright bands of different lengths, fading towards the ends, and overlapping each other, thus producing a series of maxima and minima of brightness. Near wave-length 5000 the intensity rapidly falls off towards the less refrangible side, and the bands appear detached. The middle of each of the three most intense maxima approximately coincide with the hydrogen lines $H\beta$, $H\gamma$, $H\delta$, and on two photo-plates, March 18 to 20 and March 25, each of the bands is crossed by a sharp Fraunhofer line. On the photo-plates taken after 1901 August 1 the bands are all detached; some, including the two bands whose middles approximately coincide with the principal nebular lines, have almost the same lengths, and suggest a line spectrum in which the lines have been broadened into bands, others are considerably longer and have pronounced maxima.

While it was probable that the three hydrogen lines and the two principal nebular lines were represented in the spectrum by bands, it remained to be proved that the wave-length of a definite point of the band bore a definite relation to the wave-length of the line to which it belonged. As a result of my investigations, founded on micrometric measurements and estimates of intensity, I shall show that the bands which contain a series of reversals are similar in type, and that the ratio of the distance between any two points in a band to that between corresponding points in another band is the ratio between the wave-lengths. The spectrum of Nova Aurigæ resembled that of Nova Persei very closely; its changes followed the same course, and it showed the considerable broadening of the lines into bands, the structure of which has, however, never been investigated. The systematic broadening of the spectral lines into bands, which for Nova Persei amounted to a 35th of the wave-length in March and

* Read June 6, 1904 before the Royal Society of Edinburgh.

† Professor of Astronomy in the University of Glasgow.

April, and a 100th after August, seems to be a feature of new stars, and ought to be accounted for in an explanation of these objects.

2. *The Spectrograph.*—The spectrograph of 8 cm. aperture is connected to the Breadalbane reflector of 51 cm. aperture and 446 cm. focal length. The equatorial mounting of this instrument, probably made by the late Thomas Grubb some fifty years ago, is remarkable in so far as its inclined stand anticipates the chief structural feature of the Potsdam astrographic refractor. The reflector, which had proved useless in its old condition, obtained in 1895 a new silver-on-glass mirror, driving clock with electric control, driving sector and declination clamp with slow motion, all from the works of Sir Howard Grubb. The mounting of the spectrograph was supplied by a local smith. A platform forming a right-angled triangle extends from the upper end of the tube to the free end of the declination axis, and its plane is inclined thirty-five degrees to the optical axis. Parallel to it the central ray of the reflector is reflected by a plane mirror. The platform is a stiff structure for its weight. It consists of two layers of corrugated iron, with the corrugations crossed and bolted at every point of contact, and it is strengthened by thin sheet steel ribs. To it is clamped a quarter-inch steel sole-plate, with adjustable bearings for the two tubes of the spectrograph, and on this sole-plate a small cast-iron table carrying the prism-box can be adjusted and clamped. The platform rests at its upper end, a corner of the triangle, on a casting which is bolted to the tube of the reflector; at its lower end, the shortest side of the triangle, it is screwed to a strong cast-iron arm, which is fixed to the declination axis in place of the balancing weights, at right angles to this axis and the axis of the tube. As I had the declination axis lengthened, and the telescope tube shortened and placed more favorably in its cradle, the movable part of the instrument weighs now less than in its old condition.

The object-glass of the collimator has an aperture of 8.2 cm. and focal length of 74 cm.; that of the camera, a Cooke triplet, 8.9 cm. by 149 cm. The focal length of both combined has a large temperature coefficient, 0.13 mm. for a degree centigrade. The prism made by Hilger of white Jena flint glass measures 16.5 cm. on a side, and is 9.5 cm. in height. Since it was re-annealed its separating power is most satisfactory. The central portion of the spectrograph is enclosed in a box, and by means of a small heating apparatus the temperature of the prism and the object-glasses can, at least to some extent, be kept under con-

trol. Unfortunately, the instrument cannot be used in summer after a sunny day, because in the iron dome the large prism is heated in such a way that the definition becomes too bad for accurate work.

The jaws of the slit are formed by the two halves of a circular mirror 2.5 cm. in diameter, and they open symmetrically 0.15 mm. for a revolution of the screw. The width here employed was usually 0.018 mm. The plane of the mirrors which form the jaws of the slit is inclined seven degrees to the plane normal to the central ray. If the image of the star does not fall on the slit, the rays are reflected towards a small mirror which is fixed to the telescope tube, and thence towards a viewing "telescope" (which is focussed on the slit) of 7 cm. aperture and 30 cm. focal length (two object-glasses mounted close together). It lies almost parallel to the collimator. Owing to the large size of the jaws of the slit, the effective field is half a degree, which is a great convenience in finding a star and setting it on the slit. The spark apparatus is hinged to the platform in front of the slit. When turned into position, the optical axis of its lens coincides with that of the collimator.

The collimator lens, though a fine object-glass, F/9, did not prove to be achromatised for photographic rays; the focal curve of the spectrograph runs along zero from D to Hβ, then gradually rises, and at wave-length 3700 the ordinate is 2.8 cm. I had therefore to incline the photographic plate up to 30°.

When the telescope is turned through twenty-four hours of hour-angle, the image in the focal plane of the spectrograph oscillates in simple harmonic motion, with an amplitude of 0.8 mm., along a line which is slightly inclined to the spectral lines. I compensated this deficiency of the mounting by making the plate-holder adjustable in the direction of the spectral lines, and at right angles to them, the motion being effected by two micrometer screws of 0.5 mm. pitch. The plate-holder takes the plate, 11 by 4 cm., in its upper half, which lies central in a camera, and in the space below it carries an eye-piece with stout cross wires. As fiducial line for keeping the plate stationary with regard to the spectrum, I employed the magnesium line 4481, which is almost covered by the stout wire in the eye-piece. A split spring, which presses against the jaws of the slit, cuts out a short line from the upper portion of the slit 1.5 cm. above the optical axis, and the magnesium terminals are placed close to it, inside a short glass tube, to guard the slit against tarnishing. By these means I am able to keep a line of the spectrum al-

ways on the same place of the photographic plate, and to replace the plate after days it its old position. The differential change of dispersion due to changes of temperature is, of course, not taken into account. During an exposure of the plate I moved the plate-holder every time 0.01 revolution of the micrometer screws, at intervals given by a table, and checked the position once an hour direct on the magnesium line. To illustrate the efficiency of this method, I mention that on photoplate No. 23, comparison lines at a distance of 0.04 mm. appear separated, though they were exposed on twelve different occasions, five seconds each time, on two days, and at different hour-angles.

At the time the new star was announced, wave-length 5200 t.m. was in the centre of the field of the camera, and 4000 at the end of the plate. No change was made in the position of the camera until the beginning of October 1901, when wave-length 4170 was placed in the centre.

The distance of the hydrogen lines $H\beta$ $H\gamma$ is 20 mm. on the plate, and one-tenth metre or Angstrom unit is represented on the plate by 0.1 mm. at $\lambda = 3500$, 0.05 mm. at $\lambda = 4300$, and 0.025 mm. at $\lambda = 5200$ t.m.

3. *The Measurements and their Reduction to Wave-Lengths.*—The plates taken in March and April 1901, and again those after January 1902, were difficult to measure,—the former, owing to the gradual change of intensity of the spectrum, which presented few definite points to set on; the latter, owing to the faintness of the spectrum, some parts of which could barely be distinguished from the accidental markings on the film. I finally adopted the rule to measure every point to which the eye was drawn, except those which I thought to be defects in the film. With respect to these, I became more careful as the work advanced; and it is possible that the earlier plates may contain more than were actually measured of the minima, or reversals, which were present in the spectrum during the whole period. On the plates taken between August 1901 and January 1902 the structure of the bands, including the minima, is easily seen, and in some bands it is visible to the unaided eye. The intensity of the spectrum between every two points measured was estimated on an arbitrary scale, the estimated "degrees" of intensity increasing with the intensity. In this paper the "intensity of the spectrum" stands for the intensity of blackness on the negative, while "intensity of radiation" is used for the intensity of light in the focal plane of the spectrograph. I measured each plate about

four times, alternately in opposite directions. Each series includes a number of settings on the lines of the comparison spectrum, iron-calcium until September, and iron-titanium afterwards. The points measured on the same plate were then identified by a graphical process, and all those were discarded which had not been repeatedly observed. Only on plate No. 5 I made an exception, where, after the discussion was finished, I included two minima which had only once been measured. Since the measuring occupied about half a year, and no measurements were taken after the reductions were begun, the results of the different plates may be considered independent. For each plate I reduced each series of measurements separately to wave-lengths, and then combined them to mean values. The tables used in the reductions give the position of the micrometer screw of the measuring apparatus, referred to an arbitrary zero, for each wave-length at an interval of one tenth-metre; they are based on Ketteler's formula of dispersion,* and were prepared for the angles of inclination at which the plates were exposed.

The comparison spectrum determines the correction curve of the zero of the table.

The foregoing is four pages of the introductory part of a very important paper on the spectrum of Nova Persei and the structure of its bands. It would no doubt interest some of our readers if we had given the entire paper in all its details and its conclusions in the authors own words. This was impossible for us to do, because it contains forty octavo pages with eighteen tables and two large plates which could be reproduced only with difficulty in view of the size of the page of this publication.

The foregoing introductory part of the paper will certainly interest practical workers who have given some attention to this new star, because of the instruments and methods employed. They may be profitably compared with those which some American astronomers have used with some degree of success.

Any practical observer who may care to know of the detail of the routine and tabular work or the graphical illustrations with the full explanations accompanying them, should have a copy of the paper for this information.

In concluding his paper the author mentions three results from this investigation, that are especially note-worthy. They are as follows:—

1. The spectrum consists of a line spectrum in which each line

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* *Annalen der Physik und Chemie*, 1881, 12.

is broadened into a band, the broadening being proportional to the wave-length of the line and independent of the element.

The position of the maxima and of the minima or reversals remains unchanged during the whole period 1901 March to 1902 November.

2. The intensity curve of the spectrum in March and April is satisfied by the hydrogen and helium lines, some of which vary in intensity during this period. It is probable that the spectrum is due to hydrogen and helium.

3. From August 1, 1901, to the end of 1902 the bands belong to the lines of the spectrum of planetary nebulæ, and their relative intensities converge those of the average nebular spectrum. Probably the March-April spectrum is also faintly present during the whole period.

It is to be regretted that we can not give a fuller account of this paper at the present time. W. W. P.

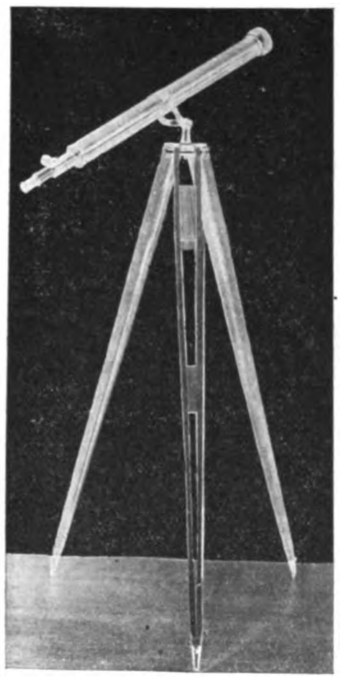
THE THREE-INCH TELESCOPE. II.

WM. W. PAYNE.

In last month's issue of this publication, we described, somewhat in detail, a three-inch telescope, which seems to us well adapted to the wants of high schools and academies, which either have not the means to secure a larger telescope, or do not care to pursue the study of the elements of astronomy further than a good three-inch instrument will well illustrate. The instrument so described, we purchased with a view of testing it carefully to see just what it would do, with the intention of publishing the results for the information of any who might be interested. The nights on which the new telescope was tried were not good observing nights; so the best the instrument can do was not then fully shown.

In the further study of the work a three-inch telescope ought to do, we may say that the usual tests of its power are those which show (1) How it divides close double stars; (2) How it defines test objects and (3) What its space penetrating power is. In regard to dividing close double stars, test objects that are suitable for any telescope are chosen by aid of the Dawes formula which is $\frac{4.''56}{a}$, the a being the clear aperture of the object-glass of the instrument, in inches. If we ~~break~~ take $a = 3$, then theoretically, the three-inch telescope ought to divide a

double star, the distance of whose components is as much as 1″.52 of arc apart. To do this fairly, the condition of the atmosphere ought to be, at least, fairly good to secure a clean, distinct separation of the components of the double star. When viewing double stars at or near the limit of the dividing power of the instrument, sometimes the test star will appear as a single disk elongated. Such results are not satisfactory as tests, or, for any other use except to suggest the probability of duplicity,



if that fact is not already known. The empirical formula, given above, and credited to Dawes is very generally accepted among astronomers as fairly correct, but not all scholars of reputation agree. Dallmeyer preferred $\frac{4''.33}{a}$. That means that a three-inch telescope should divide a double star whose components are 1″.45 of arc apart; a little stronger test than that which the previous formula requires.

It will be borne in mind that the double stars which ought to be used for the test of dividing power of the three-inch telescope should be those whose components are nearly of the same mag-

nitude. The difference of the brightness of the two components should not be much greater than one magnitude. In such cases the test for this quality of the telescopes will be fairly applied, the purpose of the dividing test being to show how nearly the makers have come, in any particular instrument, to the theóretical standard of the best that can be made. Below is given a list of stars belonging to this class of test objects.

We also give a second list of double stars whose components differ from those of the preceding class. Each pair in this class, consists of a bright star and a faint, or a comparatively close, companion. These defining tests will show how well the makers have done their work in trying to secure perfection of figure for the object-glass.

A third list of double stars is given to furnish tests for the lightgathering power of the instrument or, its space penetrating power, as it is sometimes called. It will be noticed that this third list of stars is made up of those doubles whose components are more unequal than either of the other two. Such pairs are chosen for the purpose of determining whether or not the telescope can gather enough light to reach and reveal faint companion stars more or less buried in the light of their **near and** brilliant primaries.

We have arranged these three groups of stars nearly in the order in which they shoud stand for increasing severity of test until the theoretical limit for a three-inch telescope is reached. These tests are only a few of the many that might be chosen, and probably not all the best that might have been selected; but they seem to the writer sufficient for the purpose in hand.

Amateurs who may be interested in these trial tests will bear in mind that delicate work of this kind requires good observing conditions and a good eye at the telescope for the best results.

Dividing Tests For a Three-Inch Glass.

		Distance. ″	Magnitudes.	
33	Orionis	1.76	6.0	7.0
12	Lyncis	1.70 8.7	5.7 6.4	7.4
85	Persei	1.69	6.8	7.1
λ	Ophiuchi	1.65	4.4	5.4
μ	Libræ	1.51	5.2	6.2
187	Ceti	1.50	7.1	7.3

Defining Tests For a Three-Inch Glass.

		Distance, ″	Magnitudes.	
o	Cephei	2.59	5.2	7.6
49	Leonis	2.39	6.2	8.4
70	Ophiuchi	2.05	4.3	6.2
84	Virginis	3.56	5.7	8.0
23	Aquilæ	3.33	5.7	9.0

SPACE-PENETRATING TESTS.

		Distance.	Magnitudes.	
		"		
59	Aurigæ	22.2	6.7	10.0
λ	Geminorum	9.5	3.5	9.8
57	Pegasi	32.8	5.2	10.0
ν	Ursæ Maj.	7.0	3.5	9.6
δ	Equulei	40.0	4.5	10.0
α	Tauri	115.0	1.1	10.3
β	Delphini	3.55	3.5	10.6

For the last two weeks the weather has been so unfavorable constantly, that no opportunity has come for a trial of any of these tests. We regret this very much, for what we know of this new three-inch telescope, leads us to believe that it will stand well under the severest test that can be made of it.

The few stars which we have given above are very easily found by the aid of any good star map, such as Proctor's, or that of Upton, or from the star guide by Clark and Sadler. In indentifying them, an opera glass would be of service, if the amateur wishes to work rapidly. We shall continue to look for an opportunity to use, at least some of the tests given above.

OCCULTATIONS OF STARS IN THE HYADES, DEC. 20, 1904.

H. C. WILSON.

A rather interesting series of occultations of stars by the Moon will occur on the evening of Dec. 20, 1904, when the Moon passes through the Hyades group in the constellation Taurus. The frontispiece chart shows the apparent path of the Moon's center through the group, line *AB* representing the path as seen from the center of the Earth and *MN* that seen from Northfield. The difference between the two apparent paths is due to the parallax of the Moon, which was carefully computed in preparing the chart. The figures 2^h to 9^h indicate the hours of Central Standard time when the Moon's center will be at the several points marked. On *MN* I have also marked off the ten-minute divisions of the hours. The circles represent the apparent size of the Moon.

The star positions on the chart were located by placing tracing cloth over an enlargement of a photograph of the Hyades, and platting with pen and ink the more prominent star images. The positions of α, γ and ε, had first been platted to scale and the enlargement of the photograph was made to fit the same scale. The faintest stars shown on the chart are of about the ninth magnitude. These are the photographic magnitudes, which in

many cases do not agree with the visual magnitudes.

At Northfield the Moon will rise at 3^h 27^m P. M., Central time and so the occultations of the stars θ_1 and θ_2 will occur too near the horizon to be observed. Their emersions may be caught at about 4^h 30^m and 4^h 36^m. At about 4^h 35^m the advancing edge of the Moon will reach the star B. A. C. (British Association Catalogue) 1391. This is a star of the fifth magnitude and its sudden disappearance behind the edge of the Moon will be interesting to note. Four or five minutes later the 7.5 magnitude star B. A. C. 1394 will also be covered. The Moon on that night will be only two days from the full so that fainter stars cannot be observed. The exact moment of the immersion or disappearance of the brighter stars will be much easier to note than their emersion or re-appearance, because in the former case not only is the star in sight up to the moment of its disappearance but also the phenomenon occurs at the dark edge of the Moon, while the emersion occurs at the bright edge and the star comes into sight unexpectedly and often at a different spot from that at which the observer is looking.

After an interval of about an hour the star B. A. C. 1391 will emerge as suddenly as it disappeared, very close to the west point of the Moon's limb, at 5^h 36^m as near as can be read from the chart. Two or three minutes later B. A. C. 1394 will also be uncovered at a point a little farther south on the Moon's limb.

At 6^h 01^m the Moon will reach the 7.5 magnitude star B. A. C. 1406 and will measure its diameter in passing that star in about 1^h 08^m, the star emerging at 7^h 09^m, approximately.

The star Aldebaran (α Tauri) will then be close to the east edge of the Moon and at 7^h 16^m the observer may have the exquisite pleasure of witnessing this famous red star of the first magnitude as its light is cut off in an instant by the encroaching dark edge of our satellite. Again an interval of an hour and ten minutes, more or less, and the ruddy star will emerge almost at the west point of the Moon's disk, regaining its splendor as instantly as it lost it.

Let the reader, as he contemplates the phenomenon, think for a moment of the comparative size of the two bodies; the one apparently small but really large, a giant among suns, yet so distant that its millions of miles of diameter are covered in an instant by the intervening Moon; the other apparently large but really small, yet so near that its paltry 2,000 miles of diameter not only cover the giant Sun but cover it millions of times over.

The times given in this note will serve only for the vicinity of

Northfield. The corresponding data for Washington are given in the table of Occultations visible at Washington. For other localities it will be necessary to compute the correction for the Moon's parallax, which varies greatly with the Moon's position in the heavens.

The following table gives the Moon's right ascension and declination, and its equatorial horizontal parallax and semi-diameter, as seen from the center of the Earth, for the hours of the occultations referred to.

Central Standard Time.	R.A.			Decl.			Equa. Hor. Parallax.		Radius.	
h	h	m	s	°	′	″	′	″	′	″
2	4	15	31.7	+16	12	59	56	37	15	27
3	4	17	45.4	+16	18	17	56	38	15	27
4	4	19	59.4	+16	23	31	56	40	15	28
5	4	22	13.6	+16	28	39	56	41	15	28
6	4	24	28.0	+16	33	43	56	43	15	29
7	4	26	42.8	+16	38	41	56	44	15	29
8	4	28	57.8	+16	43	34	56	46	15	30
9	4	31	13.0	+16	48	22	56	48	15	30

The Moon will be on the meridian at Greenwich Dec. 20, 10^h $24^m.6$ G. M. T. and at Northfield at 16^h $50^m.7$ G. M. T. or 10^h $50^m.7$ Central Standard time, the change for each hour of longitude being 2.17 minutes.

SPECIAL TELEGRAPHIC TIME SIGNAL FROM THE NAVAL OBSERVATORY.

WM. W. PAYNE.

On September 8, 1904, an evening reception was given, at the Naval Observatory, Washington, D. C., to the Eighth International Geographical Congress that was then in session at that place. As an interesting incident for this reception, C. M. Chester, Rear-Admiral U. S. N., Superintendent of the Naval Observatory had previously arranged with the various telegraph and cable companies of the world, for the transmission of a midnight telegraphic time-signal, on that day, in order to show to the Geographic Congress, the promptness and effectiveness of the Washington Time Service for the distribution of correct time over wide areas.

At the close of the reception, the members of the Congress interested assembled in the rooms of the Department of Chronometers, to witness the trial of sending a time signal to all parts of the world, by the beating of the Observatory clock in Washington over all telegraph and cable lines connected with the clock, and otherwise free so that the one clock could operate them all simultaneously.

At five minutes before twelve, on the evening of September 8, all was in readiness for the trial. Hon. Paul Morton, Secretary of the Navy, turned on the current, and immediately the clock began to make its ticks on the long lines everyway and everywhere, omitting one second at each half minute, and five seconds at the end of each minute, up to the last minute, at which time there was a break of ten seconds, after which a single tick marked the exact time of the Washington midnight.

The telegraph and cable companies coöperating in the distribution of this midnight time-signal were as follows:—Western Union, Postal Telegraph and Commercial Cable, Central and South American Telegraph, Telegraph Dept. Canadian Pacific Ry. Gov't Telegraph Service, Dominion of Canada, Chief Signal Officer, U. S. Army. Hydrographer to the Bureau of Equipment, Naval Department.

In a few minutes after the close of the signal, replies began to be received, and much interest was felt in them by those members of the Congress who remained to participate in this part of the program. Thirty-six replies by telegraph are reported to have been received. They were from the following sources:—Pres. Diaz, of Mexico; Pres. Francis, of the Louisiana Purchase Exposition, St. Louis; Adelaide Obs'y, Australia, (two messages); Melbourne Obs'y, Australia; Sydney Obs'y, Australia; Wellington Obs'y, New Zealand; Madras Obs'y, India; Royal Obs'y, Mauritius; Royal Obs'y, Cape Town, S. Africa; Astronomer Royal, Greenwich, England; Pulkowa Obs'y, Russia; Royal Obs'y, Libson, Portugal; Royal Obs'y, Madrid, Spain; Royal Obs'y, Roman College, Rome, Italy; Cordoba Obs'y, Argentina; Rio Janeiro Obs'y, Brazil; Quito Obs'y, Ecuador; National Obs'y, Tacubaya, Mexico; McGill College Obs'y, Montreal, Canada; Toronto Obs'y. Meteorological Service, Canada; Naval Governor of Guam, Ladrone Islands; Commandant of Naval Station, Honolulu, H. I.; Commanding Officer of Marine Barracks, Sitka, Alaska; Observatory of Harvard University, Cambridge, Mass.; Lick Obs'y. Mt. Hamilton, Cal.; Yerkes Obs'y, Williams Bay, Wis.; Observatory of Princeton University, N. J.; Lowell Obs'y, Flagstaff Arizona; Goodsell Obs'y, Northfield, Minn.; Washburn Obs'y, Madison, Wis.; Chamberlain Obs'y, Denver, Col.; Laws Obs'y, Columbia, Mo.; Allegheny Obs'y, Allegheny, Pa.; Obs'y at Mare Island, Navy Yard, Cal.; Branch Hydrographic Office, New York.

Only a portion of the replies gave the interval of time occupied in the transmission of the time-signal message. This is to be re-

gretted for the reason that it is very desirable to know how efficient the telegraph and cable service is for very long distance work. The question is now being discussed, whether or not it is now possible and desirable to have one system of time for the whole world. No doubt this trial and some others in recent time have been made by parties interested for the purpose of furnishing evidence to bear in this important question. Below we give the results of this last trial in regard to time-interval for the transmission from all the replies that contained it:

Source.			Telegraph Co.		Interval. m s
Adelaide	Obs'y.	Australia	Western Union		11 35
"	"	"	Postal		14
Melbourne	"	"	Western Union		9 00
Sydney	"	"	Postal		2.25
Madras	"	India	Western Union		53.5
Mauritius	"		" "		17 47.
Cape Town	"	Africa	Postal & W. U.		2 35
Madrid	"	Spain	Western Union		2 30
Roman	"	Italy	" "	(early)	10
Cordoba	"	Argentina	" "		2
Rio Janeiro	"	Brazil	" "		19 41.4
Quito	"	Ecuador	" "		2 1.
Toronto	"	Canada	" "		0.12
Sitka Officer,		Alaska	" "	(early)	38.9
Harvard	Obs'y,	Cambridge	Western Union		00.1
Lick	"	Mt. Hamilton, Calif.	" "	(early)	00.24
Goodsell	"	Northfield, Minn.	" "		00.10
Washburn	"	Madison, Wis.	" "		00.30
Chamberlain	"	Denver, Col.	" "		00.07
Laws	"	Columbia, Mo.	" "		00.54
Mare Island	"	California	" "	(early)	00.32
Allegheny	"	Allegheny, Pa.	" "		00.42

Under date of Oct. 6, the Superintendent of the Naval Observatory makes the following statement which has reference to intervals marked "early" in the preceding list. He says: "It may be added that the reported receipt, in some cases, of the time signals at a time earlier than when they started, probably means that the latter portion of the five-minute series of signals failed to get through telegraphs or cables, so that the final signal received started earlier than midnight. The above record is very impressive as indicating the perfection of a system by means of which the Naval Observatory clock can be practically heard around the world, and a message from the Congress delivered and acknowledged within a very few minutes from points as far away as Adelaide, Guam and Mauritius."

The long intervals in a few cases are perplexing if the wire connection was continuous. If messages were repeated at any point in transmission to Mauritius or Rio Janeiro, for example, an interval of a few minutes might be necessary.

The two messages from Adelaide Observatory, Australia, one by the Western Union and the other by the Postal Co., show a remarkable difference of time interval. The routes of transmission were very different but that fact is not alone sufficient to explain the great difference of time needed for transit.

We are under obligations to the Superintendent of the Naval Observatory for a very full account of the details of this special time-signal experiment, the substance of which it is a pleasure to give to our readers.

In a circular sent Aug. 31, 1904, to observatories generally, preparatory to a general coöperation in the time-signal of Sept. 8, the following statement occurs which may be compared with what precedes. It relates to a similar signal that was sent New Years' Eve, from Washington with the results for time intervals of transmission as given below:—

	s
Lick Observatory, California	0.05
National Observatory, City of Mexico	1.19
Royal Observatory, Greenwich, England	1.33
Sidney Observatory, Australia	3.50
Wellington Observatory, New Zealand	4.00

There is very little doubt but that a time-signal could be devised and could be distributed all over the world effectively if the means now available for such service were put to the task systematically.

SUNSPOT VARIATION IN LATITUDE.*

BY E. WALTER MAUNDER, F. R. A. S.

In his letter, under the above title, in the August number of this journal Dr. Lockyer complains that Father Cortie and myself have misunderstood the meaning of the term "spot-activity track" which he has originated. I think this complaint has no justification in fact. Certainly, for myself, I did not suppose that he intended the term to apply to the proper motion of any individual spot, but it is abundantly clear that he did intend to intimate by it that the spots were gathered together in certain districts or regions, separated from each other by broad barren intervals, and that these districts, rich in spots, moved continuously downwards towards the equator; so that the entire "eleven-year period" was the summation of three, four, or five separate and distinct shorter cycles of activity. Dr. Lockyer himself applies the term "zone" to these districts; he has drawn

* *Knowledge and Scientific News*, October, 1904.

them in his diagrams as distinct, widely separated, areas, each one moving continuously towards the equator; and his descriptions of them perfectly accord with his diagrams. He writes:—

"From sun-spot minimum to minimum there are three, but generally four distinct 'spot-activity tracks,' or loci of movements of the centres of action of spot disturbance." (*Proc. R. S.*, Vol. LXXIII., p. 147.)

Again:—

"These 'spot-activity tracks' have possibly a terrestrial equivalent in the variations from year to year of the positions of the 'Zugstrassen' or cyclone tracks of Köppen, it having been found that cyclones in general, which move in the direction of the great mass of air carried by primary currents, have a strong tendency to pursue somewhat the same tracks according to the place of origin." (*Ibid*, p. 147.)

Yet again:—

"Spoerer's Law of Spot Zones is only approximately true, and gives only a very general idea of sun-spot circulation. Spoerer's curves are the integrated result of two, three, and sometimes four 'spot-activity track' curves, each of the latter falling nearly continuously in latitude." (*Ibid*, p. 152.)

Again, speaking at the Royal Astronomical Society, on 1903, May 8, Dr. Lockyer said:—

"The general idea about the spot zones is that spots begin in a zone in high latitudes (about $\pm 30°$ to $\pm 35°$), and this zone gradually approaches the equator until the spots vanish about latitude $\pm 5°$, the new cycle commencing again in $\pm 35°$. Now a glance at this diagram* shows that this is far from correct, because sometimes there are two, and occasionally three spot zones in existence in one hemisphere at one moment. Take the case of the year 1893, when you have three zones. The curves of Spoerer are, therefore, very misleading, for by taking the mean position of several spot zones you arrive at a latitude in which spots may not exist at all." (*Observatory*, 1903, June, p. 236.)

It was because these descriptions answered to nothing on the Sun that I communicated a "Note on the Distribution of Sun-spots in Heliographic Latitude" to the Royal Astronomical Society at its last meeting. I explained therein the nature of the mistake which Dr. Lockyer had made with regard to the maxima on which he based his paper, and that his method of joining them up so as to show apparent lines of drift was not only purely arbitrary, but was often against very distinct and positive evidence.

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* The diagram of my paper communicated to the Society at this meeting, 1903, May 8.

Is Dr. Lockyer's statement that his "*spot-activity* tracks" "are *not* tracks on the solar disc," and that his paper, read before the Royal Society in 1904, February 11, has been "misunderstood," intended as a withdrawal of these descriptions and definitions of "spot-activity tracks" which I have quoted—in fact, of all the main body of his paper? If so, I think it was a pity to publish in "*Knowledge and Scientific News*" a diagram to explain how he had been led to take up a position which he now finds to be untenable.

Dr. Lockyer objects to the note on p. 159 in this journal for July, and claims that Father Cortie rather corroborated than opposed his result. I do not so read Father Cortie's paper. His words are:—

"These facts, however, as to the persistence of the disturbance in definite regions at some epochs, and dearth of spots at others, do not lend much countenance to the view of the variation in latitude being affected by a series of 'spot-activity tracks.'" (*Monthly Notices*, Vol. LXIV., p.766.)

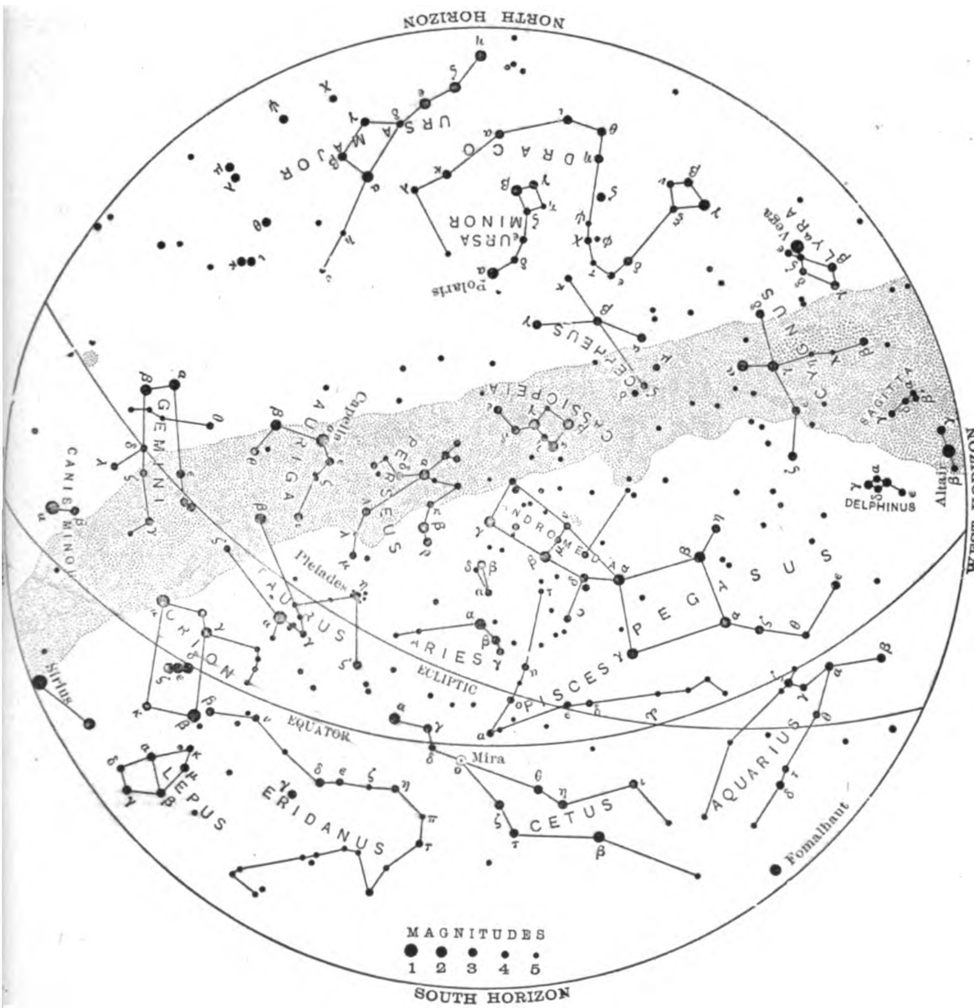
The last two sentences in Dr. Lockyer's letter form a claim which ought not to have been made. He says:

"I pointed out, as one of the main results of my investigation, that outbursts of spots in high latitudes are not restricted simply to the epochs at or about a sun-spot minimum, but occur even up to the time of sun-spot maximum." ("*Knowledge and Scientific News*," 1904, August, p. 182).

Dr. Lockyer's "investigation," so far as it relates to the years 1874-1902, consisted solely in taking the results of my paper, prepared by the desire of the Astronomer Royal for the Royal Astronomical Society, 1903, May 8, and adding the figures there given, in sets of ten, of five, and of three. A computer of average skill would do this easily in a couple of hours. But the effect of this treatment would not be to bring out the fact to which he alludes, but rather to obscure it. He found the fact ready to his hand, explicitly set forth in three-fold fashion in this paper of mine upon which he was avowedly working. It was set forth in the diagrams, in the numerical tables, and in the brief preliminary text. The latter ran thus:—

"Spots in a higher latitude than 33° were at all times rare, and when seen were never large or long-lived. Taking them as a class by themselves they were seen irregularly, appearing at times which did not seem to bear any fixed relation to any one of the four chief stages of the sun-spot cycle—minimum, increase, maximum, and decline. Omitting these spots in very high latitudes—a term which would cover a zone 10° wide in each hemisphere, from 33° to 42°, for no spots were observed in a latitude

greater than 42°—the years of maximum, 1883 and 1893, showed spots in practically every latitude between 30° north and 30° south, and they were numerous from about 8° to 24° in both hemispheres." (*Monthly Notices*, Vol. LXIII, p. 452.)



THE CONSTELLATIONS AT 9 P. M. DECEMBER 1, 1904.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be evening star in December and will be visible for a few days during the middle of the month. The planet will be at greatest eastern elonga-

tion, 20° 30′ from the Sun, Dec. 14, and will come to inferior conjunction with the Sun on the morning of Dec. 31. It will be brightest from Dec. 14 to 20.

Venus will also be evening star, and will be a conspicuous object in the south-west for from two to three hours after sunset. The phase is gibbous, decreasing from 0.78 to 0.70 during the month, while the brightness will increase from 76 to 93.

Mars during December will be morning star, being near the meridian at 7 A. M. The ruddy planet is passing through the constellation Virgo and during the last days of the month will be between three and four degrees north of the first magnitude star Spica. The apparent diameter of the planet is quite small, increasing from 5″ to 6″ during December, so that the surface markings will be seen with difficulty.

Jupiter is seen towards the south at a good altitude in the early evening. He far surpasses in brightness any star in this part of the heavens. The red belts and the four satellites are usually easily seen. On Dec. 16 Jupiter will be at the stationary point at the west end of the loop in his annual path among the stars and after that time his motion will be north-eastward for several months.

Saturn is to be seen towards the south-west in the early evening. On the nights of Dec. 27 and 28 Saturn and Venus will be quite near each other, the two planets being in conjunction in right ascension at 3 A. M., central standard time, on the morning of the 28th, when Saturn will be only 48′ north of Venus.

Uranus will be in conjunction with the Sun Dec. 22, and so will be invisible during the month.

Neptune will be at opposition Dec. 28, and may be observed with a telescope during most of the night. This planet's position is R. A. 6^h 32^m 24^s, Decl. + 22° 13′ on Dec. 1 and R. A. 6^h 28^m 54^s, Decl. + 22° 15′ on Dec. 31. It looks like a star of about the eighth magnitude, only its light is a little duller and its disc may be discerned if a sufficiently high power be used. No definite permanent markings have been identified upon its surface with any telescope.

The Moon.

(Central Standard Time at Northfield. Local Time 13m less.)

1904		Phases.	Rises. h	m	Sets. h	m
Dec.	6	New Moon	6	42 A. M.	4	41 P. M.
	14-15	First Quarter	12	25 P. M.	12	18 "
	22-23	Full Moon	5	04 "	8	15 A. M.
	28-29	Last Quarter	11	50 P. M.	12	12 P. M.

Occultations Visible at Washington.

Date. 1904.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Dec.	1	Mars	..	14	07	110	15	08	290	1	01
	2	ρ Virginis	4.9	15	24	88	16	19	316	0	55
	9	B.A.C.	6.0	5	56	86	7	02	246	1	06
	14	20 Piscium	5.7	10	50	62	11	54	255	1	04
	17	64 Ceti	5.7	14	20	138	14	48	195	0	28
	20	B.A.C 1391	5.0	5	21	74	6	24	254	1	03
	20	B.A.C. 1394	7.5	5	26	87	6	28	242	1	02
	20	B.A.C. 1406	7.5	6	55	90	8	06	236	1	11
	20	α Tauri	1.0	8	17	83	9	38	245	1	21
	21	111 Tauri	5.2	4	53	126	5	31	213	0	48
	21	115 Tauri	5.4	6	31	358	6	42	338	0	10
	26	B.A.C. 3538	7.0	9	32	98	10	27	288	0	55
	26	44 Leonis	6.2	10	51	98	11	53	292	1	03
	28	η Virginis	4.1	13	56	145	14	54	262	0	58

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

	h	m		
Dec. 1	6	08	P. M.	III Tr. Eg.
	8	16	"	III Sh. In.
	10	12	"	III Sh. Eg.
2	10	55	"	I Tr. In.
	11	57	"	I Sh. In.
3	8	13	"	I Oc. Dis.
	11	26	"	I Ec. Re.
4	5	22	"	I Tr. In.
	6	26	"	I Sh. In.
	7	35	"	I Tr. Eg.
	8	38	"	I Sh. Eg.
	9	13	"	II Oc. Dis.
5	5	55	"	I Ec. Re.
6	4	08	"	II Tr. In.
	6	21	"	II Sh. In.
	6	37	"	II Tr. Eg.
	8	50	"	II Sh. Eg.
8	7	42	"	III Tr. In.
	9	45	"	III Tr. Eg.
10	10	02	"	I Oc. Dis.
11	7	11	"	I Tr. In.
	8	21	"	I Sh. In.
	9	24	"	I Tr. Eg.
	10	34	"	I Sh. Eg.
	11	37	"	II Oc. Dis.
12	4	31	"	I Oc. Dis.
	7	51	"	I Ec. Re.
13	5	03	"	I Sh. Eg.
	6	35	"	II Tr. In.
	9	00	"	II Sh. In.
	9	05	"	II Tr. Eg.
	11	29	"	II Sh. Eg.
15	5	41	"	II Ec. Re.
	11	22	"	III Tr. In.
17	11	53	"	I Oc. Dis.
18	9	02	"	I Tr. In.
Dec. 18	10	17	P. M.	I Sh. In.
	11	16	"	I Tr. Eg.
19	12	30	A. M.	I Sh. Eg.
	6	21	P. M.	I Oc. Dis.
	6	27	"	III Ec. Dis.
	8	04	"	III Ec. Re.
	9	47	"	I Ec. Re.
20	4	46	"	I Sh. In.
	5	44	"	I Tr. Eg.
	6	58	"	I Sh. Eg.
	9	05	"	II Tr. In.
	11	35	"	II Tr. Eg.
	11	38	"	II Sh. In.
21	4	16	"	I Ec. Re.
22	5	49	"	II Oc. Re.
	5	53	"	II Ec. Dis.
	8	18	"	II Ec. Re.
25	10	54	"	I Tr. In.
26	4	57	"	III Oc. Dis.
	7	08	"	III Oc. Re.
	8	14	"	I Oc. Dis.
	10	30	"	III Ec. Dis.
	11	43	"	I Ec. Re.
27	12	06	A. M.	III Ec. Re.
	5	22	P. M.	I Tr. In.
	6	41	"	I Sh. In.
	7	36	"	I Tr. Eg.
	8	54	"	I Sh. Eg.
	11	37	"	II Tr. In.
28	6	12	"	I Ec. Re.
29	5	50	"	II Oc. Dis.
	8	21	"	II Oc. Re.
	8	30	"	II Ec. Dis.
	10	54	"	II Ec. Re.
31	6	05	"	II Sh. Eg.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new minor planets since our last note:

	Discovered by	at	Local Mean Time.	h m	R. A. h m	Decl. ° ′	Mag.
1904 OR	Kopff	Heidelberg	1904 Sept. 6	13 24.7	23 23.6	+ 7 25	12.8
OS	"	"	Sept. 5	9 16.6	17 26.5	— 4 23	12.2
OT	Götz	"	Sept. 11	12 14.0	1 04.7	+ 20 10	12.1
OU	"	"	Sept. 11	12 14.0	1 05.4	+ 20 04	12.5
OV	Kopff	"	Sept. 11	13 16.9	1 57.1	+ 25 06	13.3
OW	Götz	"	Sept. 19	13 34.9	1 19.4	+ 9 08	11.0
OX	Kopff	"	Sept. 19	14 23.3	2 10.4	+ 9 25	13.0

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U Cephei.

	d	h
Dec.	2	8
	4	19
	7	7
	9	19
	12	7
	14	19
	17	7
	19	18
	22	6
	24	18
	28	6
	30	18

Z Persei.

	d	h
Dec.	1	15
	4	17
	7	18
	10	19
	13	21
	16	22
	20	0
	23	1
	26	2
	29	4

Algol.

	d	h
Dec.	1	10
	4	7
	7	4
	10	1
	12	22
	15	18
	18	15
	21	12
	24	9
	27	6
	30	2

λ Tauri.

	d	h
Dec.	3	14
	7	13
	11	12
	15	10
	19	9
	23	8
	27	7
	31	6

R Canis Maj.

	d	h
Dec.	1	15
	2	19
	3	22
	5	1
	6	4
	7	8
	8	11
	9	14
	10	18
Dec.	11	21
	13	0
	14	3
	15	6
	16	10
	17	13
	18	16
	19	20
	20	23
	22	2
	23	5
	24	9
	25	12
	26	15
	27	18
	28	22
	30	1
	31	4

V Puppis.

	d	h
Dec.	2	12
	3	23
	5	10
	6	20
	8	7
	9	18
	11	5
	12	16
	14	3
	15	14
	17	1
	18	12
	19	23
	21	10
	22	20
	24	7
	25	18
	27	5
	28	16
	30	3
	31	14

S Cancri.

	d	h
Dec.	5	22
	15	10
	24	21

S Antliæ.

	d	h
Dec.	1	3
	2	2
	3	2
	4	1
	5	0
	6	0
	6	23
	7	22
	8	22
Dec.	9	21
	10	20
	11	20
	12	19
	13	18
	14	18
	15	17
	16	16
	17	16
	18	15
	19	14
	20	14
	21	13
	22	12
	23	12
	24	11
	25	10
	26	10
	27	9
	28	8
	29	8
	30	7
	31	6

S Velorum.

	d	h
Dec.	4	1
	8	23
	15	22
	21	20
	27	18

W. Urs. Maj.

		h
Dec.	1-20	11
	21-31	12

RR Velorum.

	d	h
Dec.	1	14
	3	11
	5	7
	7	4
	9	0
	10	21
	12	17
	14	14
	16	10
	18	7
	20	3
	22	0
	23	20
	25	17
	27	13
	29	10
	31	6

Z Draconis.

	d	h
Dec.	1	18
	3	3
	4	11
Dec.	5	20
	7	4
	8	13
	9	22
	11	6
	12	15
	13	23
	15	8
	16	16
	18	1
	19	10
	20	18
	22	3
	23	11
	24	20
	26	4
	27	13
	28	22
	30	6
	31	15

δ Libræ.

	d	h
Dec.	2	13
	4	21
	7	4
	9	12
	11	20
	14	4
	16	12
	18	20
	21	4
	23	11
	25	19
	28	3
	30	11

U Coronæ.

	d	h
Dec.	2	0
	5	11
	8	22
	8	19
	12	9
	15	19
	19	6
	22	17
	26	4
	29	15

SY Cygni.

	d	h
Dec.	3	23
	9	23
	15	23
	21	23
	27	23

SW Cygni.

	d	h
Dec.	2	10
	7	0
Dec.	11	13
	16	3
	20	17
	25	7
	29	20

UW Cygni.

	d	h
Dec.	4	1
	7	12
	10	23
	14	9
	17	20
	21	7
	24	18
	28	5
	31	16

W Delphini.

	d	h
Dec.	3	12
	8	7
	13	3
	17	22
	22	17
	27	13

VV Cygni.

	d	h
Dec.	2	3
	3	14
	5	2
	6	13
	8	1
	9	12
	11	0
	12	11
	13	22
	15	10
	16	21
	18	9
	19	20
	21	8
	22	19
	24	7
	25	18
	27	6
	28	17
	30	4
	31	16

VW Cygni.

	d	h
Dec.	5	20
	14	6
	22	17
	31	3

Y Cygni.

	d	h
Dec.	1	20
	3	11

Minima of Variable Stars of the Algol Type.—Continued.

Y Cygni.			Y Cygni			Y Cygni			Y Cygni			UZ Cygni.		
	d	h		d	h		d	h		d	h		d	h
Dec.	4	20	Dec.	12	11	Dec.	19	20	Dec.	27	11	Dec.	24	8
	6	11		13	20		21	11		28	20			
	7	20		15	11		22	20		30	11			
	9	11		16	20		24	11		31	19			
	10	20		18	11		25	20						

Approximate Magnitudes of Variable Stars Oct. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	14 *i*	R Camel.	14	25.1	+84	17	11.5*d*
T Cassiop.	0	17.8	+55	14	9 *i*	R Bootis	14	32.8	+27	10	9.5 *i*
R Androm.	0	18.8	+38	1	14	S Librae	15	15.6	—20	2	*s*
S Ceti	0	19.0	— 9	53	10 *d*	S Serpentis	15	17.0	+14	40	9.8*d*
S Cassiop.	1	12.3	+72	5	11 *i*	S Coronae	15	17.3	+31	44	12.8*d*
R Piscium	1	25.5	+ 2	22	10 *d*	S Urs. Min.	15	33.4	+78	58	8.0 *i*
U Persei	1	52.9	+54	20	8	R Coronae	15	44.4	+28	28	6
R Arietis	2	10.4	+24	36	14 *f*	V "	15	45.9	+39	52	11.2*d*
o Ceti	2	14.3	— 3	26	9.3*d*	R Serpentis	15	46.1	+15	26	9*d*
S Persei	2	15.7	+58	8	10 5 *i*	R Herculis	16	1.7	+18	38	8.5
R Ceti	2	20.9	— 0	38	10.5*d*	R Scorpii	16	11.7	—22	42	*s*
U "	2	28.9	—13	35	10.5 *i*	S "	16	11.7	—22	39	*s*
R Trianguli	2	31.0	+33	50	8.0*d*	U Herculis	16	21.4	+19	7	12.5*d*
R Persei	3	23.7	+35	20	11 *i*	W Herculis	16	31.7	+37	32	9 *i*
R Tauri	4	22.8	+ 9	56	9 *i*	R Draconis	16	32.4	+66	58	8.3 *i*
S "	4	23.7	+ 9	44	*f*	S Herculis	16	47.4	+15	7	8.5*d*
R Aurigæ	5	9.2	+53	28	13 *d*	R Ophiuchi	17	2.0	—15	58	7.5*d*
U Orionis	5	49.9	+20	10	9.8*d*	T Herculis	18	5.3	+31	0	7.8 *i*
R Lyncis	6	53.0	+55	28	8 *i*	R Scuti	18	42.2	— 5	49	5.5*d*
R Gemin.	7	1.3	+22	52	*s*	R Aquilae	19	1.6	+ 8	5	12 *d*
S Canis Min.	7	27.3	+ 8	32	*f*	R Sagittarii	19	10.8	—19	29	8 *i*
R Cancri	8	11.0	+12	2	*s*	S "	19	13.6	—19	12	*f*
V "	8	16.0	+17	36	*s*	R Cygni	19	34.1	+49	58	13.5
S Hydrae	8	48.4	+ 3	27	*s*	RT "	19	40.8	+48	32	7.7 *i*
T "	8	50.8	— 8	46	*s*	X "	19	46.7	+32	40	9 *i*
R Leo. Min.	9	39.6	+34	58	*s*	S Cygni	20	3.4	+57	42	14 *d*
R Leonis	9	42.2	+11	54	8 *d*	RS "	20	9.8	+38	28	7.5 *i*
R Urs. Maj.	10	37.6	+69	18	12 *d*	R Delphini	20	10.1	+ 8	47	11 *d*
R Comae Ber.	11	59.1	+19	20	9 *d*	U Cygni	20	16.5	+47	35	9.2*d*
T Virginis	12	9.5	— 5	29	*s*	V "	20	38.1	+47	47	13 *d*
R Corvi	12	14.4	—18	42	*s*	T Aquarii	20	44.7	— 5	31	9.5*d*
Y Virginis	12	28.7	— 3	52	*s*	R Vulpec.	20	59.9	+23	26	8.5*d*
T Urs. Maj.	12	31.8	+60	2	12.5*d*	T Cephei	21	8.2	+68	5	10 *d*
R Virginis	12	33.4	+ 7	32	*s*	S "	21	36.5	+78	10	10.5*d*
S Urs. Maj.	12	39.6	+61	38	12.8*d*	S Lacertae	22	24.6	+39	48	12.5*d*
U Virginis	12	46.0	+ 6	6	*s*	R "	22	38.8	+41	51	13 *d*
V "	13	22.6	— 2	39	*s*	S Aquarii	22	51.8	—20	53	13 *f*
R Hydrae	13	24.2	—22	46	*s*	R Pegasi	23	1.6	+10	0	8.5*d*
S Virginis	13	27.8	— 6	41	*s*	S "	23	15.5	+ 8	22	10.5 *i*
R Can. Ven.	13	44.6	+40	2	10.6*d*	R Aquarii	23	38.6	—15	50	10.8
S Bootis	14	19.5	+54	16	10 *d*	R Cassiop.	23	53.3	+50	50	13 *d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

From observations made at the Halsted, McCormick and Harvard Observatories.

Variable Stars of Short Period not of the Algol Type.

	Minimum. d	h	Maximum. d	h		Minimum. d	h	Maximum. d	h
T Vulpeculae	Dec. 1	6	Dec. 2	15	S Crucis	Dec. 16	1	Dec. 17	13
SU Cygni	1	15	2	23	U Vulpeculae	16	14	18	17
T Velorum	1	18	3	3	V Centauri	16	14	18	1
S Crucis	2	0	3	12	S Muscae	16	14	20	1
T Crucis	2	0	4	1	R Crucis	16	17	18	2
β Lyræ	2	1	5	8	SU Cygni	17	0	18	8
S Triang. Austr	2	2	4	4	TX Cygni	17	5	22	8
V Velorum	2	3	3	2	V Carinæ	17	7	19	11
W Geminorum	2	10	5	1	W Geminorum	17	22	20	13
TX Cygni	2	12	7	15	T Vulpeculae	18	23	20	8
S Sagittæ	3	8	6	18	η Aquilæ	19	11	21	20
V Carinae	3	22	6	2	V Velorum	19	14	20	13
ζ Geminorum	4	6	9	6	S Sagittae	20	2	23	12
R Crucis	5	1	6	10	T Velorum	20	8	21	17
η Aquilae	5	3	7	12	δ Cephei	20	13	21	22
δ Cephei	5	11	6	20	S Crucis	20	18	22	6
X Cygni	5	11	11	16	SU Cygni	20	20	22	4
SU Cygni	5	11	6	19	S Triang. Austr.	21	1	23	3
V Centauri	5	14	7	1	β Lyrae	21	10	24	12
T Vulpeculae	5	16	7	1	X Cygni	21	20	28	1
T Velorum	6	9	7	18	V Centauri	22	1	23	12
V Velorum	6	12	7	11	T Crucis	22	5	24	6
S Crucis	6	16	8	4	R Crucis	22	13	23	22
S Muscae	6	23	10	10	T Monocerotis	22	23	30	21
S Triang. Austr.	8	10	10	12	T Vulpeculae	23	10	24	19
β Lyræ	8	12	11	14	V Velorum	23	23	24	22
U Vulpeculae	8	14	10	17	V Carinæ	23	23	26	3
T Crucis	8	18	10	19	U Vulpeculae	24	13	26	16
SU Cygni	9	7	10	15	ζ Geminorum	24	14	29	14
δ Cephei	9	20	11	5	SU Cygni	24	16	26	0
T Vulpeculae	10	2	11	11	T Velorum	24	23	26	8
W Geminorum	10	4	12	19	S Crucis	25	11	26	23
V Carinae	10	14	12	18	W Geminorum	25	16	28	7
V Velorum	10	21	11	20	δ Cephei	25	20	27	5
R Crucis	10	21	12	6	S Muscae	26	6	29	17
T Velorum	11	1	12	10	η Aquilae	26	15	29	0
V Centauri	11	2	12	13	S Triang. Austr.	27	9	29	11
S Crucis	11	9	12	21	V Centauri	27	13	29	0
S Sagittae	11	17	15	3	T Vulpeculae	27	20	29	5
η Aquilae	12	7	14	16	β Lyræ	27	21	31	4
W Virginis	12	20	21	1	V Velorum	28	8	29	7
SU Cygni	13	4	14	12	S Sagittæ	28	11	31	21
ζ Geminorum	14	10	19	10	R Crucis	28	12	29	21
T Vulpeculae	14	13	15	22	SU Cygni	28	12	29	20
S Triang. Austr.	14	18	16	20	T Crucis	28	22	30	23
β Lyræ	14	23	18	6	T Velorum	29	14	30	23
V Velorum	15	5	16	4	W Virginis	30	2	30	7
δ Cephei	15	5	16	14	S Crucis	30	4	31	16
T Crucis	15	11	17	12	V Carinæ	30	17	32	21
T Velorum	15	16	17	1	δ Cephei	31	7	32	16

New or Variable Star.—A cablegram from Kiel Observatory states that a new star was discovered by Williams at Hove, England, September 20.674 Greenwich mean time in right ascension 22^h 19^m and declination $+29°$ 44′. The position is for the epoch 1855. The object is probably a variable star. Its magnitude was 9.0 on Sept. 20 and 9.1 on Oct. 3. Its color is very red. The position given is in the constellation Pegasus about four degrees west of the star η.

Maxima of Y Lyræ.

Period 12^h 03.9^m. The minimum occurs 1^h 40^m before the maximum.

	d	h		d	h
Dec.	1- 7	10	Dec.	16-22	12
	8-15	11		23-31	13

Maxima of UY Cygni.

Period 13^h 27^m $27^s.59$. The minimum occurs 1^h 55^m before the maximum.

	d	h		d	h		d	h		d	h
Dec.	1	15	Dec.	9	11	Dec.	17	8	Dec.	25	4
	2	18		10	14		18	11		26	7
	3	21		11	17		19	13		27	10
	5	0		13	23		20	16		28	13
	6	2		14	23		21	19		29	16
	7	5		15	2		22	22		30	19
	8	8		16	5		24	1		31	21

Maxima of RZ Lyræ.

Period 12^h 16^m $15^s.0$.

	d	h		d	h		d	h		d	h
Dec.	1	17	Dec.	9	22	Dec.	18	2	Dec.	27	7
	2	18		10	22		19	3		28	7
	3	18		11	23		20	3		29	8
	4	19		12	23		21	4		30	8
	5	19		14	0		22	4		31	9
	6	20		15	0		23	5			
	7	20		16	1		24	5			
	8	21		17	2		26	6			

Algol Variable 154. 1904 Cygni.—Professor W. Ceraski in *A. N.* 3970 gives the following elements of this variable as determined by Mr. S. Blajko of Moscow:

$$\text{Minimum} = 1904 \text{ Aug. } 29, 12^h\ 38^m \text{ Gr. M. T. } + 3^d\ 7^h\ 37^m.9\ E.$$

The error of the period probably does not exceed a half minute. At minimum the star falls below the 12½ magnitude.

New Variable Star 155. 1904 Persei.—In *A. N.* 3970 Professor W. Ceraski announces a new variable of the Algol type discovered by Mme. L. Ceraski on the photographs taken at Moscow. The star is BD. + 49° 740 and its position is

1855	3^h	13^m	$38^s.5$	+ 46°	2′.3
1900	3	16	43 .5	49	12.2

It is ordinarily of about 9.5 magnitude but every 20^h 23^m it falls to the 11th magnitude, the change of brightness occupying about 2½ hours. The following elements are given:

$$\text{Minimum} = 1904 \text{ Sept. } 17, 5^h\ 45^m \text{ Gr. M. T. } + 20^h\ 23^m\ 11^s\ E.$$

New Variable Star 156. 1904 Ceti.—On September 19, 1904, Dr. W. Luther at Düsseldorf found a ninth magnitude star in the position

$$\text{R. A.} = 1^h\ 01^m\ 51^s.2 \qquad \text{Decl.} = -1°\ 59'\ 43''$$

which is not given in the *Bonn Durchmusterung*. It has been found on nine photographs taken at Heidelberg in the years 1902-1904. These furnish the following estimates of the photographic brightness of the star:

			Mag.				Mag.
1902	Sept.	26.4	12.0	1904	Aug.	16.5	9.0
	Oct.	7.5	12.0		Sept.	5.4	9.0
1903	Sept.	23.5	11.5		"	17.5	9.1
	Nov.	9.3	13.0		"	18.5	9.3
					"	19.6	9.2

GENERAL NOTES.

Astronomical Exhibits at the World's Fair.—A visitor, interested in astronomy, who has been at the World's Fair at St. Louis reports concerning the astronomical exhibits. He says those from the Harvard and the Chicago Universities consist largely of transparencies, telescopic views enlarged of the phases of the Moon, solar eclipses, of the Sun and of star spectra. Our informant suggests that too much can not be said in praise of the German exhibit of optical and astronomical instruments, so extensive as to surpass everything else. The exhibit of astronomical instruments from the United States is said to be meager, Warner and Swasey from Cleveland, Ohio, being the only firm represented. Instruments of German make are fine, but America can do generally better than appears from this report. In what they do try there are none superior to the Warner & Swasey make.

Introduction to the Study of Spectrum Analysis.—Just as we are going to press with our last forms, a new book comes to hand, titled: An Introduction to the Study of Spectrum Analysis. It contains 325 pages and it is illustrated with colored plates and 135 cuts. It is written by W. Marshall Watts and published by Messrs. Longmans, Green, & Company, London, England, and New York. The work deserves a full notice which will appear in our next number.

Arago on Newton.—The translation of Halley's Latin Elogy on Sir Isaac Newton which is given by Mr. McPike in Vol. XII, No. 7, of POPULAR ASTRONOMY leads me to offer you a few remarks on some statements with regard to the great philosopher in Arago's *Notices Biographiques*, not for the purpose of endorsing the same but of reprobating them as utterly unworthy of credit. Arago Vites (Vol. 111, p. 335).

"J'ai appris de Lord Brougham que, pendant la guerre des Cévennes, Newton s'était préparé à aller combattre dans les rangs des Canisards les dragons du maréchal de Villars, et qu'une circonstance fortuite l'empêcha seule de donner suite à ce dessein. Comment le timide Newton se fût-il conduit sur le champ de bataille, lui qui, de crainte de tomber, ne se promenait en voiture dans les rues de Londres que les bras étendus et les mains cramponnées aux deux portières. On concevra d'après ce seul fait que la question puisse être soulevée, et devenir le sujet d'un doute."

Doubt, indeed! The whole statement is wholly incredible. Lord Brougham was born there fifty years after the death of Newton; perhaps he may have heard some tradition that the latter may have expressed in conversation sympathy with the persecuted Huguenots in the Cévennes; but that he ever seriously contemplated joining the army led by Villars against them in the way alleged is sufficiently refuted by the fact that when that general took the command in 1704, Newton was in the sixty-second year of his age, and quite past campaigning. As to his habitual timidity (the only reason Arago gives for doubting the absurd story) the only evidence offered for this is his hesitation in speaking in public, a very different thing from fearing to ride in the streets without holding on by both hands! Demosthenes and Horace, we are told, both showed cowardice on the field of battle, but Newton's in a carriage, as told by Arago, is beyond credence.

W. T. LYNN.

Orbit of Castor.—In *A. N.* 3960 Dr. W. Doberck gives new elements of the orbit of this well known double star. He finds that the observations o position angle at hand may be fairly well represented by periods ranging all the way from 200 to 600 years but that the measures of distance limit the period much more closely. He finds as the most probable period 347 years and considers this certain within ten or at most twenty years.

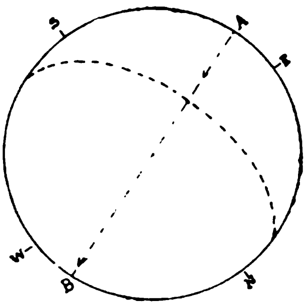
Elements of Castor.

$\Omega = 33° \ 56'$	$P = 346.82$ years
$\lambda = 82 \ \ 26$	$T = 1969.82$
$\gamma = 63 \ \ 37$	$a = 5''.756.$
$e = 0.4409$	

The following ephemeris shows the change that will take place in the position angle and distance of the two stars during the next twenty years.

	P.A.	Dist.		P.A.	Dist.
	°	"		°	"
1905	223.6	5.56	1920	216.5	5.13
1910	221.3	5.46	1925	213.8	4.90
1915	219.0	5.32			

Occultation of Mars Dec. 1, 1904.—An occultation of Mars by the Moon will occur on the night of December 1, astronomical time, or the morning of December 2, civil time. It will not be visible in the central and western part of the United States. In the eastern states the emersion, at least, may be observed but at such a low altitude that observations will not be very satisfactory. In the accompanying diagram the line *AB* represents the apparent path of Mars behind the Moon during the occultation. As seen from Washington the immersion of the planet at A will take place at $14^h \ 06^m.9$ Washington mean time, or at $2^h \ 15.^m1$ A. M., Eastern Standard time. The emersion at B will occur at $15^h \ 08^m.1$, W. M. T., or $3^h \ 16^m. \ 2$ A. M., E. S. T. As the Moon rises at about 2^h A. M. the immersion will be observed with difficulty at Washington. In southern Europe and northern Africa the conditions for observing this occultation will be more favorable.



Occultation of Mars, Dec. 1, 1904.

Comparison of the Features of the Earth and the Moon.—Professor S. P. Langley, Secretary of the Smithsonian Institution, Washington, D. C., has recently issued an important quarto publication giving a comparison of the features of the Earth and the Moon. This study has been before the mind of Professor Langley for more than twelve years. It was years ago hoped by him that the rapid advance of photography recently, would soon furnish a means of study of the minute features of the Moon that would be equally available to the geologist, the selenographer and the astronomer; for the marvelous revelation of the sensitive plate in the study of nebulæ has led the scholars to believe that wonderful results might as well be expected in other directions, but this expectation has yet been only partially fulfilled. On this account the more critical comparison of Earth and Moon, planned for years ago, Professor Langley has laid aside for the present. He has, however, published in the

volume before us, a memoir of 93 pages, by Professor Shaler, of Harvard College, on this theme, accompanying the same by twenty-five of the best photographs of the Moon and characteristic features of it, that have been recently made at the great observatories of the world.

Professor Shaler's memoir gives the result of personal studies carried on for a third of a century. He has devoted one hundred nights to the study of the Moon by the aid of the Mertz equatorial of Harvard College Observatory, his later attention being given to the photographs of the Moon at Harvard University with which he has so long been connected.

This memoir is so carefully prepared and brings the reader so well into the first line of practical work in lunar studies at the present time, that a fuller review of it is desirable. We will try in next month's issue to complete the notes.

Gore's Studies in Astronomy.—A new book is just received, bearing the title: Studies in Astronomy. It is written by J. Ellard Gore, and published by Messrs. Chatts & Windus, London, England.

The contents of this book is mainly a series of articles prepared by Mr. Gore for scientific magazines during the last few years, which he has recently revised and partly re-written and brought down to date, so that all the topics presented are brief, comprehensive, and so far as we see, carefully accurate reviews of the present state of astronomical science in regard to them.

The themes are twenty-seven in number, and comprise such as the following:

The size of the solar system; Jupiter and its system; giant telescopes, the distances of the stars, the Sun's journey through space, the story of gamma Virginis, the Pleiades, globular star clusters, the Sun's stellar magnitude, stellar satellites, spectroscopic binaries, the darkness behind the stars, the nebular hypothesis, stellar evolution, the constitution of the visible universe, etc., etc.

This partial list shows the kind of topics the author has chosen for this new volume. The treatment of these themes shows familiarity with a range of early and recent astronomical work that is gratifying to the professional astronomer. The simple direct a untechnical language employed throughout the book, brings it within the easy reach of popular readers. The facts used and the references made furnish reliable data that seem to be chosen with special care making a book very valuable for reference, as well as one interesting to read to put a person in touch with the latest information concerning the topics presented.

As an illustration, we briefly notice the fourteenth article which treats of the Nebular Hypothesis. The author first speaks of its origin, and soon comes to Herbert Spencer's thought whether Creation by manufacture or by development is the higher thing. "A man can put together a machine, but he can not make a machine develop itself." The author thinks the development theory is not incompatible with the power of the Creator. He next compares the views of Kant and Laplace, pointing out how each came to the same conclusion essentially, but in different ways, in suggesting the essentials of a theory that has stood for one hundred years. He notices the objections to the hypothesis that have been raised from time to time, put them all into four points, and answers them well and fairly, as far as the present state of astronomy can do it. He closes the article with a reference to the photographic work that has been done on the spiral nebulæ and new stars, and he brings this new evidence to bear on the nebular hypothesis with convincing effect. What has been said about this topic, could be repeated about almost every other. Mr. Gore has given popular readers a very enjoyable and a very useful book. May his ready pen continue its excellent work—popular astronomy.

Tanner's Elementary Algebra is the latest new book in the modern mathematical series that has been, for several years, in course of preparation at Cornell University, Ithaca, N. Y. It is published by the American Book Co., of Chicago, Cincinnati, New York. The book contains 350 pages besides appendices on irrational and complex numbers and the index. It covers the usual elementary subjects belonging to Algebra including quadratics, fully treated, ratio and proportion, series and the Binomial Theorem. The work is very full on the ground it covers, and it is made to meet the requirements of the College Entrance Board for Cornell University, which certainly sets a pretty high standard for elementary Algebra, if it is meant that the entire contents of the book, excepting some of the exercises must be taken for preparation to enter the University.

For those who prefer a shorter course, using the same book, a plan is suggested on page X, preceding the introduction.

That the text is thorough, scholarly, and up to date in its plan and development is assured when a mathematician and an instructor of Mr. Tanner's ability is known to have done the work of making it.

Differential and Integral Calculus by Granville.—This new book on the elements of Calculus, is prepared by W. A. Granville, instructor in mathematics in the Sheffield Scientific School of Yale University, with the editorial coöperation of Percy F. Smith, professor of mathematics in the same scientific school. It is published by Messrs. Ginn & Company, of Boston, Mass. It contains 463 pages which forms one of the most complete books for school text use, if not the most complete that has come to our notice in recent years.

The first chapter is a collection of trigonometrical formulæ and tables arranged for ready reference. The second chapter treats briefly of numbers of various kinds, including complex numbers, and expressions which reduce to $\frac{0}{0}$. Speaking of $\frac{a}{0}$, the author says, it has no meaning and is therefore excluded. The reason for rejecting this as a possible operation is that there exists no number such that if it be multiplied by 0 will produce the number a. Hence the author says that, "division by zero is not an admissible operation."

Good mathematicians do not agree in reference to this matter. Chapter third considers variables and functions, setting out fully the meaning of these terms, as they are used in the Calculus. It is well done. Chapter four discusses the theory of limits. In definition and principle, the author is clear and careful. He uses the graphs of the trigonometric functions with good effect in the study of limits. With a few exceptions the theorems and proofs usually given in this topic are employed in this text.

At chapter five, page 37, the real work of the Calculus begins, in which the operation of differentiation is fully considered. It is first developed in algebraic sense in the notation of the Calculus, and then the derivatives are applied to geometry for the sake of graphical illustration to make the meaning clear.

Chapter six deduces the rules for differentiating algebraic functions and the various classes of the transcendental functions.

Under each of these various classes of functions will be found a large number of exercises, suitable for the rules they are to illustrate. This chapter covers forty pages. In connection with the rules for the circular functions the graphs are given. The frequent fine print foot-notes are suggestive and very helpful.

The applications of the derivative are considered in chapter seven, and the range of work given in twenty-two pages is fully up to the best modern requirements for colleges and apparently for the technical schools.

Chapter eight deals with successive differentiation, and chapter nine, maxima and minima, having a large number of geometrical examples for the application of this important feature of the differential Calculus. Chapter ten considers points of inflection; eleven, differentials; twelve, rates; thirteen, change of variable; fourteen, curvature, radius of curvature; fifteen, theorem of mean value and indeterminate forms. To these two last topics sixteen pages are given.

Chapter sixteen treats of circle of curvature and center of curvature in a variety of applications with full geometrical illustrations accompanying the same. That idea is worked out capitally.

Chapter seventeen takes up partial differentiation and employs the special notation for it, and interprets a partial derivative with a geometrical illustration. The formulæ here derived are put in heavy-faced type for ready reference. Chapter eighteen consider envelopes; nineteen, series; twenty, expansion of functions. The author, we think, is wise in separating series from the expansion of functions. His graphical representation of series to show the interval of convergence is just what we have used to give and tangible ideas to students who are studying this theme by the Calculus for the first time. When the intervals of convergence and equivalence and the tests for them can be readily and certainly given, the expansions of functions will be carried much more easily.

Chapter twenty-one has to do with asymtotes, singular points and curve tracing.

Chapter twenty-two applies the Calculus to the geometry of space in nine pages and chapter twenty-three gives the graphs of thirty curves for reference with the name and equation belonging to each.

The differential Calculus, as described fills 287 pages of this book, and 187 is given to the integral Calculus. The same general plan is adopted in treating this part of the text, as is employed in the first part.

The strong points in the new book are:—Its orderly arrangement, its clearness in definition and proofs, its fullness without unnecessary detail, its ample graphic illustration, its large lists of exercises its many useful notes and its finely printed pages. Those who will master this book in a year's study will know something about the elements of the Calculus.

The Royal Astronomical Society of Canada.—A pamphlet of 144 pages containing the selected papers and proceedings of the Royal Astronomical Society of Canada, for the years 1902 and 1903 has been received. It is edited by Arthur Harvey, F. R. S. C., having as a frontispiece, a fine picture of the late George Edward Lumsden, president of the Toronto astronomical society in 1900 and 1901. Those who know of the strong Toronto astronomical society will notice that the association has been reorganized, and apparently put on a permanent basis for scientific work. Besides the usual officers, it has a limited list of fifteen honorary fellows, and a limited list of twenty-four corresponding fellows. Seven of the honorary fellows are from the United States. Fourteen of the twenty-four corresponding fellows have been selected already, and three of these are American astronomers. There are also patrons, life fellows, associate, and foreign members. Under the new organization and in the new name, this Royal Society seems to stand on a par with those of the other English possessions.

It is the purpose of the publication to make a record of important papers presented to the Society and the business transacted by it.

This volume contains fourteen papers with title as follows: A history of the

Magnetic and Meteorological Observatory at Toronto; A catalogue of Aerolites, Shooting Stars vs. Uranoliths, Astronomical equipment of Canada, Greenwich Observatory, To be an Astronomer, the Sun and Solar radiations, the Moon, the Earth as a planet, Radium, The Spectrum of Uranium, the Constitution of matter, Seeing a storm through a telescope, Variability of the light of the stars. Womens' work in Astronomy. This first volume under the new organization is very creditable one.

Errata.—The misprints on page 571, last issue, in Mr. McPike's note are regretted. Confusion might arise over "Rigurd" which should read "Rigaud."

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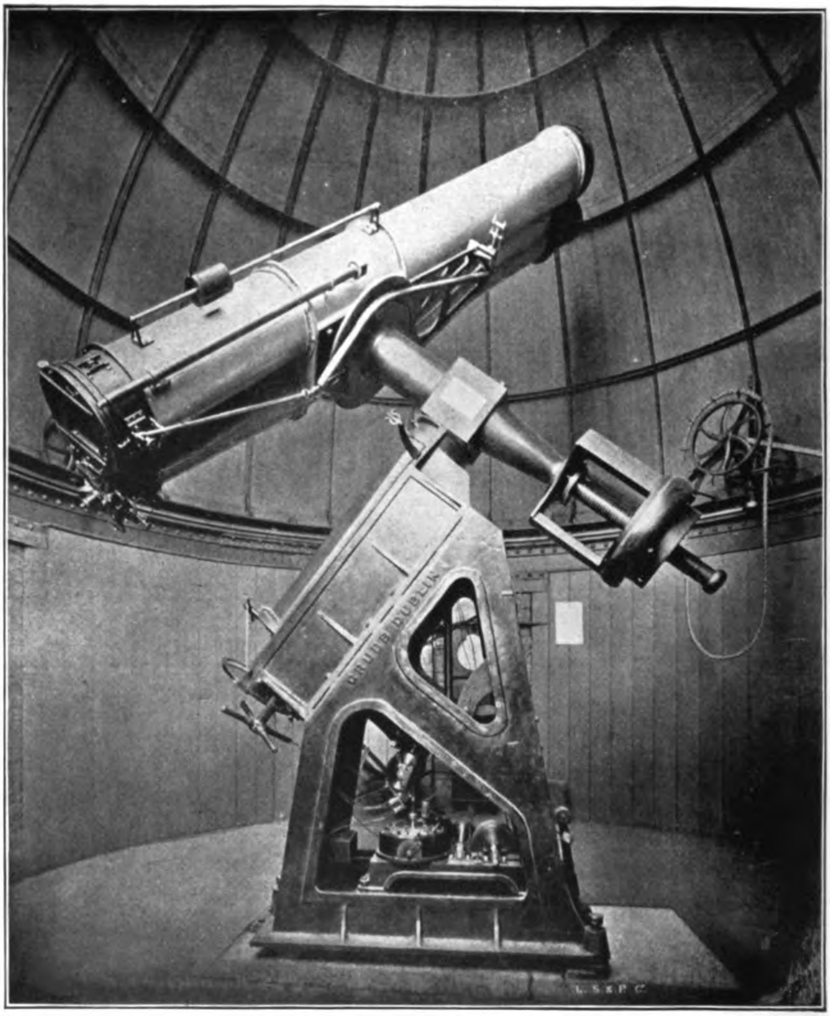
PLATE XXIII.



Astrographic Equatorial at Greenwich.

Popular Astronomy No. 120.

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Vol. XII No. 10. DECEMBER, 1904. Whole No. 120.

CULTURE VALUE OF MATHEMATICS AND ASTRONOMY II.

WM. W. PAYNE.

In the first part of this article, found on page 585 of this publication, we called attention to the way mathematics has been thought of to some extent, when its branches are being pursued in the schools, and, sometimes, when estimates of its culture value are under consideration.

We emphasized the study of mathematics as a means of rigorous mental discipline, because such study furnishes a field for systematic training with steps of logical sequence that are satisfactorily exact and uniquely strong. We also ventured to suggest that the study of mathematical truth for its own sake, instead of seeking its knowledge for business advantage in practical life, would furnish a motive to enlist mental energy that would be peculiarly effective. As illustrations of this fact, a few of the early scholars in mathematics were named, the methods of their work briefly outlined, and the success that crowned their efforts summarized, using Newton as the great example of scholarly possibility from a profound and almost life-long study of mathematics. In this connection we did not say the half that might be told of this great man, bearing on the means and the methods of his intellectual training, for the simple reason that some of our readers might think that the sources of Newton's greatness had not been rightly estimated. Newton is sometimes spoken of as a genius in mathematics, meaning that he had, by nature, intuitive insight and a spontaneous grasp in mathematical thinking far beyond the average range of the scholarship of his times, and that a genius can not be compared with a student who must work long and hard for every thing he gets in his plodding mental growth. This position is partly wrong and partly right. There are those in every line of scholarship that specialize exhaustively, and that, as a consequence stand in the front rank

of discovery in the realm of new thought, or, those who have a power, almost at will, to do wondrously and almost intuitively the large things that occupy their minds. In this mental condition, however explained, the mathematician is no exception. As an illustration of it, we think of the most extraordinary and inconsistent life of the celebrated Cardan. History says, he was "a gambler, if not a murderer; he was also an ardent student of science, solving problems which had long baffled all investigation; at one time in his life he was devoted to intrigues which were a scandal even in the sixteenth century, at another he did nothing but rave on astrology, and yet at another time he declared that philosophy was the only subject worthy of man's attention. His was a genius closely allied to madness."

We are not considering this kind of genius, but that other which, with good natural gifts, makes its way through mountains of difficulty and opposition by the dint of hard work. There are plenty of such in every age. History is replete with most entertaining and stirring accounts of the deeds and lives of those who have had a genius of the better and the higher kind. This phase has been sufficiently indicated in what has already been said in the introductory part of this article.

In this connection it seems best to notice what has been recently said in a carefully prepared paper,* by a prominent educator belonging to one of the eastern universities. An extract from this paper is as follows.

"Pure mathematics is concerned with the investigation of the logical consequences of certain exactly statable postulates or hypotheses—such, for instance, as the postulates upon which arithmetic and analysis are founded, or such as the postulates that lie at the basis of any type of geometry. For the pure mathematician, the truth of these hypotheses or postulates depends, not upon the fact that physical nature contains phenomena answering to the postulates, but solely upon the fact that the mathematician is able, with rational consistency, to state these assumed first principles, and to develop their consequences. Dedekind, in his famous essay, 'Was Sind und Was Sollen die Zahlen,' called the whole numbers 'freie Schöpfungen des Menschlichen Geistes'; and, in fact, we need not enter into any discussion of the psychology of our number concept in order to be able to assert that, however we men first came by our con-

*The Sciences of the Ideal," an address delivered before the St. Louis Congress of Arts and Science by Professor Joseph Royce of Harvard University. *Science* Oct. 7,p. 449.

ception of the whole numbers, for the mathematician the theory of numerical truth must appear simply as the logical development of the consequences of a few fundamental first principles, such as those which Dedekind himself, or Peano, or other recent writers upon this topic, have, in various forms, stated. A similar formal freedom marks the development of any other theory in the realm of pure mathematics. Pure geometry, from the modern point of view, is neither a doctrine forced upon the human mind by the constitution of any primal form of intuition, nor yet a branch of physical science, limited to describing the spatial arrangement of phenomena in the external world. Pure geometry is the theory of the consequences of certain postulates which the geometer is at liberty consistently to make; so that there are as many types of geometry as there are consistent systems of postulates of that generic type of which the geometer takes account. As is also now well known, it has long been impossible to define pure mathematics as the science of quantity, or to limit the range of the exactly statable hypotheses or postulates with which the mathematician deals to the world of those objects which, ideally speaking, can be viewed as measurable. For the ideally defined measurable objects are by no means the only ones whose properties can be stated in the form of exact postulates or hypotheses; and the possible range of pure mathematics, if taken in the abstract, and viewed apart from any question as to the value of given lines of research, appears to be identical with the whole realm of the consequences of exactly statable ideal hypotheses of every type.

One limitation must, however, be mentioned, to which the assertion just made is, in practise, obviously subject. And this is, indeed, a momentous limitation. The exactly stated ideal hypotheses whose consequences the mathematician develops must possess, as is sometimes said, sufficient intrinsic importance to be worthy of scientific treatment. They must not be trivial hypotheses. The mathematician is not, like the solver of chess problems, merely displaying his skill in dealing with the arbitrary fictions of an ideal game. His truth is, indeed, ideal; his world is, indeed, treated by his science as if this world were the creation of his postulates a 'freie Schöpfung.' But he does not thus create for mere sport. On the contrary, he reports a significant order of truth. As a fact, the ideal systems of the pure mathematician are customarily defined with an obvious, even though often highly abstract and remote, relation to the structure of our ordinary, empirical world. Thus the various algebras which

have been actually developed have, in the main, definite relations to the structure of the space world of our physical experience. The different systems of ideal geometry, even in all their ideality, still cluster, so to speak, about the suggestions which our daily experience of space and of matter give us. Yet I suppose that no mathematician would be disposed, at the present time, to accept any brief definition of the degree of closeness or remoteness of relation to ordinary experience which shall serve to distinguish a trivial from a genuinely significant branch of mathematical theory. In general a mathematician who is devoted to the theory of functions, or to group theory, appears to spend little time in attempting to show why the development of the consequences of his postulates is a significant enterprise. The concrete mathematical interest of his inquiry sustains him in his labors, and wins for him the sympathy of his fellows. To the question, 'Why consider the ideal structure of just this system of object at all?' 'Why study various sorts of numbers, or the properties of functions, or of groups, or the system of points in projective geometry?'—the pure mathematician in general, cares to reply only, that the topic of his special investigation appears to him to possess sufficient mathematical interest. The freedom of his science thus justifies his enterprise. Yet, as I just pointed out, this freedom is never mere caprice. This ideal interest is not without a general relation to the concerns even of common sense. In brief, as it seems at once fair to say, the pure mathematician is working under the influence of more or less clearly conscious philosophical motives. He does not usually attempt to define what distinguishes a significant from a trivial system of postulates, or what constitutes a problem worth attacking from the point of view of pure mathematics. But he practically recognizes such a distinction between the trivial and the significant regions of the world of ideal truth, and since philosophy is concerned with the significance of ideas, this recognition brings the mathematician near in spirit to the philosopher.

Such, then, is the position of the pure mathematician. What, by way of contrast, is that of the philosopher? We may reply that to state the formal consequences of exact assumptions is one thing; to reflect upon the mutual relations, and the whole significance of such assumptions, does indeed involve other interests; and these other interests are the ones which directly carry us over to the realm of philosophy. If the theory of numbers belongs to pure mathematics, the study of the place of the number concept in the system of human ideas belongs to philos-

ophy. Like the mathematician, the philosopher deals directly with a realm of ideal truth. But to unify our knowledge, to comprehend its sources, its meaning, and its relations to the whole of human life, these aims constitute the proper goal of the philosopher. In order, however, to accomplish his aims, the philosopher must, indeed, take account of the results of the special physical science; but he must also turn from the world of outer phenomena to an ideal world. For the unity of things is never, for us mortals, anything that we find given in our experience. You can not see the unity of knowledge; you can not describe it as a phenomenon. It is for us now, an ideal. And precisely so, the meaning of things, the relation of knowledge to life, the significance of our ideals, their bearing upon one another —these are never, for us men, phenomenally present data. Hence the philosopher, however much he ought, as indeed he ought, to take account of phenomena, and of the results of the special physical sciences, is quite as deeply interested in his own way, as the mathematician is interested in his way, in the consideration of an ideal realm. Only, unlike the mathematician, the philosopher does not first abstract from the empirical suggestions upon which his exact ideas are actually based, and then content himself merely with developing the logical consequences of these ideas. On the contrary, his main interest is not in any idea or fact in so far as it is viewed by itself, but rather in the inter-relations, in the common significance, in the unity, of all fundamental ideas, and in their relations both to the phenomenal facts and to life! On the whole, he, therefore, neither consents, like the student of a special science of experience, to seek his freedom solely through conformity to the phenomena which are to be described; nor is he content, like the pure mathematician, to win his truth solely through the exact definition of the formal consequences of his freely defined hypotheses. He is making an effort to discover the sense and the unity of the business of his own life.

It is no part of my purpose to attempt to show here how this general philosophical interest differentiates into the various interests of metaphysics, of the philosophy of religions, of ethics, of esthetics, of logic. Enough—I have tried to illustrate how, while both the philosopher and the mathematician have an interest in the meaning of ideas rather than in the description of external facts, still there is a contrast which does, indeed, keep their work in large measure asunder, viz., the contrast due to the fact that the mathematician is directly concerned with develop-

ing the consequences of certain freely assumed systems of postulates or hypotheses; while the philosopher is interested in the significance, in the unity and in the relation to life, of all the fundamental ideals and postulates of the human mind.

Yet not even thus do we sufficiently state how closely related the two tasks are. For this very contrast, as we have also suggested, is, even within its own limits, no final or perfectly sharp contrast. There is a deep analogy between the two tasks. For the mathematician, as we have just seen, is not evenly interested in developing the consequences of any and every system of freely assumed postulates. He is no mere solver of arbitrary ideal puzzles in general. His systems of postulates are so chosen as to be not trivial, but significant. They are, therefore, in fact, but abstractly defined aspects of the very system of eternal truth whose expression is the universe. In this sense the mathematician is as genuinely interested as is the philosopher in the significant use of his scientific freedom. On the other hand, the philosopher, in reflecting upon the significance and the unity of fundamental ideas, can only do so with success in case he makes due inquiry into the logical consequences of given ideas. And this he can accomplish only if upon occasion, he employs the exact methods of the mathematician, and develops his systems of ideal truth with the precision of which only mathematical research is capable. As a fact, then, the mathematician and the philosopher deal with ideal truth in ways which are not only contrasted, but profoundly interconnected. The mathematician, in so far as he consciously distinguishes significant from trivial problems, and ideal systems, is a philosopher. The philosopher, in so far as he seeks exactness of logical method, in his reflection, must meanwhile aim to be, within his own limits, a mathematician. He indeed, will not in future, like Spinoza, seek to reduce philosophy to the mere development, in mathematical form, of the consequences of certain arbitrary hypotheses. He will distinguish between a reflection upon the unity of the system of truth and an abstract development of this or that selected aspect of the system. But he will see more and more that, in so far as he undertakes to be exact, he must aim to become, in his own way, and with due regard to his own purposes, mathematical; and thus the union of mathematical and philosophical inquiries, in the future, will tend to become closer and closer.

So far, then, I have dwelt upon extremely general considerations relating to the unity and the contrast of mathematical and philosophical inquiries. I can well conceive, however, that the

individual worker in any one of the numerous branches of investigation which are represented by the body of students whom I am privileged to address, may at this point mentally interpose the objection that all these considerations are, indeed, far too general to be of practical interest to any of us. Of course, all we who study these so-called normative sciences are, indeed, interested in ideas, for their own sakes—in ideas so distinct from, although of course also somehow related to, phenomena. Of course some of us are rather devoted to the development of the consequences of exactly stated ideal hypotheses, and others to reflecting as we can upon what certain ideas and ideals are good for, and upon what the unity is of all ideas and ideals. Of course if we are wise enough to do so, we have much to learn from one another. But, you will say, the assertion of all these things is a commonplace. The expression of the desire for further mutual co-operation is a pious wish. You will insist upon asking further: "Is there just now any concrete instance in a modern type of research which furnishes results such as are of interest to all of us? Are we actually doing any productive work in common? Are the philosophers contributing anything to human knowledge which has a genuine bearing upon the interests of mathematical science? Are the mathematicians contributing anything to philosophy?"

These questions are perfectly fair. Moreover, as it happens, they can be distinctly answered in the affirmative. The present age is one of a rapid advance in the actual unification of the fields of investigation which are included within the scope of this present division. What little time remains to me must be devoted to indicating, as well as I can, in what sense this is true. I shall have still to deal in very broad generalities. I shall try to make these generalities definite enough to be not wholly unfruitful.

We have already emphasized one question which may be said to interest, in a very direct way, both the mathematician and the philosopher. The ideal postulates, whose consequences mathematical science undertakes to develop, must be, we have said, significant postulates, involving ideas whose exact definition and exposition repay the labor of scientific scrutiny. Number, space, continuity, functional correspondence or dependence, group-structure—these are examples of such significant ideas; the postulates or ideal assumptions upon which the theory of such ideas depends are significant postulates, and are not the mere conventions of an arbitrary game. But now what con-

stitutes the significance of an idea, or of an abstract mathematical theory? What gives an idea a worthy place in the whole scheme of human ideas? Is it the possibility of finding a physical application for a mathematical theory which for us decides what is the value of the theory? No, the theory of functions, the theory of numbers, group theory, have a significance which no mathematician would consent to measure in terms of the present applicability or non-applicability of these theories in physical science. In vain, then, does one attempt to use the test of applied mathematics as the main criticism of the value of a theory of pure mathematics. The value of an idea, for the sciences which constitute our division, is dependent upon the place which this idea occupies in the whole organized scheme or system of human ideas. The idea of number, for instance, familiar as its applications are, does not derive its main value from the fact that eggs and dollars and star-clusters can be counted, but rather from the fact that the idea of numbers has those relations to other fundamental ideas which recent logical theory has made prominent—relations, for instance, to the concept of order, to the theory of classes or collections of objects viewed in general, and to the metaphysical concept of the self. Relations of this sort, which the discussions of the number concept by Dedekind, Cantor, Peano and Russell have recently been brought to light—such relations, I say constitute what truly justified Gauss in calling the theory of numbers a 'divine science.' As against such deeper relations, the countless applications of the number concept in ordinary life, and in science, are, from the truly philosophical point of view, of comparatively small moment. What we want, in the work of our division of the sciences, is to bring to light the unity of truth, either, as in mathematics, by developing systems of truth which are significant by virtue of their actual relations to this unity, or, as in philosophy, by explicitly seeking the central idea about which all the many ideas cluster.

Now, an ancient and fundamental problem for the philosophers is that which has been called the problem of the categories. This problem of the categories is simply the more formal aspect of the whole philosophical problem just defined. The philosopher aims to comprehend the unity of the system of human ideas and ideals. Well, then, what are the primal ideas? Upon what group of concepts do the other concepts of human science logically depend? About what central interests is the system of human ideals clustered? In ancient thought Aristotle already approached this problem in one way. Kant, in the eighteenth

century, dealt with it in another. We students of philosophy are accustomed to regret what we call the excessive formalism of Kant, to lament that Kant was so much the slave of his own relatively superficial and accidental table of categories, a d that he made the treatment of every sort of philosophical problem turn upon his own schematism. Yet we can not doubt that Kant was right in maintaining that philosophy needs, for the successful development of every one of its departments, a well-devised and substantially complete system of categories. Our objection to Kant's over-confidence in the virtues of his own schematism is due to the fact that we do not now accept his table of categories as an adequate view of the fundamental concepts. The efforts of philosophers since Kant have been repeatedly devoted to the task of replacing his scheme of categories by a more adequate one. I am far from regarding these purely philosophical efforts made since Kant as fruitless, but they have remained, so far, very incomplete, and they have been held back from their due fulness of success by the lack of a sufficiently careful survey and analysis of the processes of thought as these have come to be embodied in the living sciences. Such concepts as number, quantity, space, time, cause, continuity, have been dealt with by the pure philosophers far too summarily and superficially. A more thoroughgoing analysis has been needed.

But now, in comparatively recent times, there has developed a region of inquiry which one may call by the general name of modern logic. To the constitution of this new region of inquiry men have principally contributed who began as mathematicians, but who, in the course of their work, have been led to become more and more philosophers. Of late, however, various philosophers, who were originally in no sense mathematicians, becoming aware of the importance of the new type of research, are in their turn attempting both to assimilate and to supplement the undertakings which were begun from the mathematical side. As a result, the logical problem, of the categories has today become almost equally a problem for the logicians of mathematics and for those students of philosophy who take any serious interest in exactness of method in their own branch of work. The result of this actual co-operation of men from both sides is that, as I think, we are today, for the first time, in sight of what is still, as I freely admit, a somewhat distant goal, viz., the relatively complete rational analysis and tabulation of the fundamental categories of human thought. That the student of ethics is as

much interested in such an investigation as is the metaphysician, that the philosopher of religion needs a well-completed table of categories quite as much as does the pure logician, every competent student of such topics ought to admit. And that the enterprise in question keenly interests the mathematicians is shown by the prominent part which some of them have taken in the researches in question. Here, then, is the type of recent scientific work whose results most obviously bear upon the tasks of all of us alike.

A catalogue of the names of the workers in this wide field of modern logic would be out of place here. Yet one must, indeed, indicate what lines of research are especially in question. From the purely mathematical side, the investigations of the type to which I now refer may be viewed (somewhat arbitrarily) as beginning with that famous examination into one of the postulates of Euclid's geometry which gave rise to the so-called non-Euclidean geometry. The question here originally at issue was one of a comparatively limited scope, viz., the question whether Euclid's parallel-line postulate was a logical consequence of the other geometrical principles. But the investigation rapidly develops into a general study of the foundations of geometry—a study to which contributions are still almost constantly appearing. Somewhat independently of this line of inquiry there grew up, during the latter half of the nineteenth century, that re-examination of the bases of arithmetic and analysis which is associated with the names of Dedekind, Weierstrass and George Cantor. At the present time, the labors of a number of other inquirers (among whom we may mention the school of Peano and Pieri in Italy, and men such as Poincaré and Couturat in France, Hilbert in Germany, Bertram Russell and Whitehead in England and an energetic group of our American mathematicians—men such as Professor Moore, Professor Halsted, Dr. Huntington, Dr. Veblen and a considerable number of others) have been added to the earlier researches. The result is that we have recently come for the first time to be able to see, with some completeness, what the assumed first principles of pure mathematics actually are. As was to be expected, these principles are capable of more than one formulation, according as they are approached from one side or from another. As was also to be expected, the entire edifice of pure mathematics, so far as it has yet been erected, actually rests upon a very few fundamental concepts and postulates, however you may formulate them. What was not observed, however, by the earlier, and especially by the philosoph-

ical, students of the categories, is the form which these postulates tend to assume when they are rigidly analyzed.

This form depends upon the precise definition and classification of certain types of relations. The whole of geometry, for instance, including metrical geometry, can be developed from a set of postulates which demand the existence of points that stand in certain ordinal relationships. The ordinal relationships can be reduced, according as the series of points considered is open or closed, either to the well-known relationship in which three points stand when one is between the other two upon a right line, or else to the ordinal relationship in which four points stand when they are separated by pairs; and these two ordinal relationships, by means of various logical devices, can be regarded as variations of a single fundamental form. Cayley and Klein founded the logical theory of geometry here in question. Russell, and in another way Dr. Veblen, have given it its most recent expressions. In the same way, the theory of whole numbers can be reduced to sets of principles which demand the existence of certain ideal objects in certain simple ordinal relations. Dedekind and Peano have worked out such ordinal theories of the number concept. In another development of the theory of the cardinal whole numbers, which Russell and Whitehead have worked out, ordinal concepts are introduced only secondarily, and the theory depends upon the fundamental relation of the equivalence or non-equivalence of collections of objects. But here also a certain simple type of relation determines the definitions and the development of the whole theory.

Two results follow from such a fashion of logically analyzing the first principles of mathematical science. In the first place, as just pointed out, we learn *how few and simple are the conceptions and postulates* upon which the actual edifice of exact science rests. Pure mathematics, we have said, is free to assume what it chooses. Yet the assumptions whose presence as the foundation principles of the actually existent pure mathematics an exhaustive examination thus reveals, show by their fewness that the ideal freedom of the mathematician to assume and to construct what he pleases, is indeed, in practise, a very decidedly limited freedom. The limitation is, as we have already seen, a limitation which has to do with the essential significance of the fundamental concepts in question. And so the result of this analysis of the bases of the actually developed and significant branches of mathematics, constitutes a sort of empirical revelation of what categories the exact sciences have practically found

to be of such significance as to be worthy of exhaustive treatment. Thus the instinctive sense for significant truth which has all along been guiding the development of mathematics, comes at least to a clear and philosophical consciousness. And meanwhile the essential categories of thought are seen in a new light.

The second result still more directly concerns a philosophical logic. It is this: Since the few types of relations which this sort of analysis reveals as the fundamental ones in exact science are of such importance, the logic of the present day is especially required to face the questions: *What is the nature of our concepts of relations?* What are the various possible types of relations? Upon what does the variety of these types depend? What unity lies beneath the variety?

As a fact, logic, in its modern forms, viz., first that symbolic logic which Boole first formulated, which Mr. Charles S. Peirce and his pupils have in this country already so highly developed, and which Schroeder in Germany, Peano's school in Italy and a number of recent English writers, have so effectively furthered —and secondly, the logic of scientific method, which is now so actively pursued, in France, in Germany and in the English-speaking countries—this whole movement in modern logic, as I hold, is rapidly approaching *new solutions of the problem of the fundamental nature and the logic of relations.* The problem is one in which we are all equally interested. To De Morgan in England, in an earlier generation, and, in our time, to Charles Peirce in this country, very important stages in the growth of these problems are due. Russell, in his work on the 'Principles of Mathematics,' has very lately undertaken to sum up the results of the logic of relations, as thus far developed, and to add his own interpretations. Yet I think that Russell has failed to get as near to the foundations of the theory of relations as the present state of the discussion permits. For Russell has failed to take account of what I hold to be the most fundamentally important generalization yet reached in the general theory of relations. This is the generalization set forth as early as 1890, by Mr. A. B. Kempe, of London, in a pair of wonderful, but too much neglected, papers, entitled, respectively, 'The Theory of Mathematical Form,' and 'The Analogy between the Logical Theory of Classes and the Geometrical Theory of Points.' A mere hint first as to the more precise formulation of the problem at issue, and then later as to Kempe's special contribution to that problem, may be in order here, despite the impossibility of any adequate statement."

If we had the space for it, the whole address of which the above is an extract, would have been very profitable reading for any one interested in the culture value of the study of pure mathematics, to see just what ground its several branches cover, their relations to one another, and especially the relation of pure mathematics to the whole realm of philosophy including the field of modern logic.

This thought of the advantage of mental culture to be found in the realm of the applied mathematics is still more important and more complex than that of pure mathematics, if one but realizes the endless field of application that is now open in every direction. This phase of our subject which includes astronomy will be considered at another time.

THE WATSON ASTEROIDS.

BURT L. NEWKIRK.*

James C. Watson was born in the province of Ontario, Canada, January 28, 1838. He graduated at the University of Michigan in 1857, and became Professor of Astronomy and Director of the Observatory of that institution six years later. He was one of our most prominent astronomers, having written a book on theoretical astronomy which is still very widely used in the United States. He died in 1880, at the age of forty-two years. During the course of his scientific career he discovered twenty-two asteroids, and at his death left a sum of money as an endowment fund, the income from which should be used to pay for certain investigations and computations which it is necessary to make in order that these asteroids may not be lost to the scientific world.

Beside the well-known greater planets the Sun's system contains a host of very minute planets called asteroids. They revolve about the Sun in the space between the orbits of *Mars* and *Jupiter*. The first one of these to be discovered was found upon the first night of the nineteenth century, the night of January 1, 1801. This is the asteroid *Ceres*, and it is the brightest, and presumably the largest, of the group, having a diameter of 600 miles. Since the introduction of photographic methods in the search for these bodies, their discovery has been made comparatively easy, and something over five hundred of them have

* Read at the meeting of the Society held in Berkeley January 30, 1904.

already been found, every year adding twenty or thirty to the list. At the time of Watson's death, in 1880, less than two hundred had been found. The smallest of these bodies are probably nothing more than great rocks, ten or fifteen miles in diameter. Smaller asteroids than these undoubtedly exist, but are so exceedingly faint as to elude discovery.

Of all the planets of the Sun's system these asteroids offer the greatest difficulties in the matter of the investigation of their orbits. We say, roughly speaking, that the planets move about the Sun in elliptical orbits; but, more accurately speaking, none of the bodies composing the Sun's system move in ellipses. According to Newton's law of gravitation, every particle of matter attracts every other particle. If the Sun were attended by one planet only, this planet would move in an ellipse, but since each planet is attracted not only by the Sun, but also by all other planets, its path is a curve of corresponding complexity. Since the Sun's attraction is generally by far the most powerful of all the forces acting upon any one planet, it is convenient to think of the actual orbit described by a planet as a "disturbed ellipse," as we express it. We picture to ourselves an ellipse which nearly coincides with the actual orbit, and in which the planet would move if the attractive forces of the other planets should at some particular instant cease to operate. The departure of the true orbit from this assumed ellipse, due to the disturbing action of the other planets is called the perturbation of the planet under consideration. The only reason for taking an ellipse as a starting-point in the discussion is one of convenience. A circle, which is a simpler curve from a mathematical point of view, might answer the purpose in some cases better than an ellipse, and for other purposes it is advantageous to take as a starting-point a curve of greater complexity. I refer to the "periplegmatic" curves used by Gyldén, which represent the path of the planet throughout a long period of years much better than any ellipse could, but seem to possess no advantages in tracing the planet's motion for a short period of time. It is a comparatively simple matter to compute an elliptic orbit, but to investigate the deviations from this orbit—i. e. the perturbations of a planet—is a task requiring in some cases a tremendous amount of labor and study.

The mathematical difficulties of the problem are such that no general method can be employed for computing the orbits of all the planets. Each planet must be treated with reference to the special difficulties which it presents, and this necessitates an in-

telligent and discriminating study of the various methods used in investigations of this nature, their advantages and their limitations.

The method employed in any particular case must not only be mathematically correct, but it must also be capable of yielding the desired results with the required degree of accuracy and with a minimum of numerical computation. The method of most general application is one developed by Hansen, and modified by Hill, Newcomb, and others. Newer methods which possess special advantages in certain cases have been developed by Gyldén, Bohlin, and Brendel. These latter methods are, however, comparatively untried, and it has been found necessary here in the asteroid work at Berkeley to revise Bohlin's method to some extent, before employing the formulæ given. Upon opening correspondence with Bohlin, whose method has been used on some asteroids here, Professor Leuschner found that Bohlin himself had arrived at the same conclusion and was at work upon a revision of his theory.

In the case of the asteroids the problem presents special difficulties because of the proximity of *Jupiter*, which is the largest planet, and exerts a very powerful disturbing force. In most cases, in fact, unless a high degree of accuracy is required, the effect of all the other planets combined is a negligible quantity as compared with the perturbations produced by *Jupiter*. Difficult as the problem is, it is however, absolutely necessary to compute the perturbations if we would keep the asteroids from retiring again into the oblivion from which their discoverers drew them. It is not possible to predict the motion of an asteroid ten or fifteen years in advance with sufficient accuracy to permit of its being found again at the end of that time without serious difficulty unless this work is done.

In the light of these remarks, Professor Watson's object in endowing the twenty-two asteroids discovered by himself will be clear. If their perturbations are not derived, his asteroids will be lost to the world in a few years, but, thanks to the fund he has bequeathed for this purpose, it will be possible to predict their motion for fifty or seventy-five years in advance with sufficient accuracy to enable astronomers of the future to find them again when they are wanted without serious difficulty. One of the twenty-two must be excepted from this statement. The asteroid *Aethra*, whose original path passed close to that of *Mars*, has suffered such violent perturbation that the form of its orbit has been greatly changed, and it has not been identified

since, in spite of the diligent search which has been made for it. The tracing of the motion of this planet by means of a special mathematical discussion, which will be an exceedingly difficult matter, is to be undertaken by Miss Hobe, who is now engaged with me upon the perturbations of the other asteroids, under the direction of Professor Leuschner.

Since Professor Watson's death, in 1880, the trustees have been trying to carry out the desire expressed in his will, by preparing tables by means of which the motion of these asteroids can be predicted for, say, fifty years in advance, with sufficient accuracy to permit of their being readily found. Up to two years and a half ago, when the work was undertaken by this department, considerable has been done, but little was ready for publication. Since that time the perturbations of ten planets have been computed here in Berkeley, and those of two more are nearing completion. Five others are to be treated by Bohlin's method, the work on these being already under way: the four remaining asteroids have been made the subject of investigation by other astronomers in Europe and America.

Perhaps the most important result of the investigations of the orbits of the Watson asteroids is the light thrown upon the whole subject of asteroid orbits and the methods best adapted to the various cases that arise. The treatment of twenty-two asteroids yields data which will be very valuable in the solution of one of the great problems which now confronts mathematical astronomy,—namely, that of providing tables by means of which the position of any one of the known asteroids may be found without excessive labor.

Before our tables for finding the planets in future years can be finished it will be necessary to compare the results of our investigations with observations. It is possible by this means greatly to improve the results of the numerical work. For this purpose the photographic telescope and Repsold measuring apparatus will be available. With the help of these instruments we shall be able to observe the positions of the asteroids, and a comparison of observations with theory will lead to a final improvement of the tables before publishing them.

The Watson trustees have, as may be imagined from the long time that has elapsed since Professor Watson's death without the completion of the task, had great difficulty in getting the work done satisfactorily. They have, however, been very well pleased with the progress made here by Drs. Crawford and Ross, under the supervision of Professor Leuschner, and have now

turned the whole work over to the latter to be completed and prepared for publication. The work is being carried on under the auspices of the National Academy of Sciences, and the present Watson trustees are: Professor Simon Newcomb (chairman), Professor Lewis Boss, and Professor W. L. Elkin. It is their intention to have all the results published in due time. It has, however, seemed fitting upon this occasion to offer to those interested in the Berkeley Astronomical Department this brief statement of our connection with the undertaking.

SOLAR AND SIDEREAL TIME.

ARTHUR K. BARTLETT.

It is a fact not generally known that, owing to the difference between solar and sidereal time, the Earth rotates upon its axis once more often than there are days in the year. The Earth performs one complete rotation upon its axis in 23 hours, 56 minutes, and 4.09 seconds of solar time. This is called a "sidereal day," because in that time the stars appear to complete one revolution around the Earth. But, as the Earth advances almost a degree eastward in its orbit, in the time that it turns eastward around its axis, it is easy to understand that just one rotation never brings the same meridian around from the Sun to the Sun again; so that the Earth requires as much more than one complete rotation upon its axis to complete a "solar day" as it has gone forward in that time. It will be obvious therefore, that in every natural or solar day, the Earth performs one complete rotation upon its axis, and the 365th part of another rotation. Consequently, in 365 days, the Earth turns 366 times upon its axis; and as every rotation of the Earth upon its axis completes a "sidereal day," there must be 366 sidereal days in a year.

The same considerations will apply to our neighbor worlds of the solar system, and since the rotation of any planet upon its axis is the length of a sidereal day at that planet, the number of sidereal days will always exceed the number of solar days by one, let that number be what it may, one rotation being always lost in the course of an annual revolution. This difference between the solar and sidereal days may be illustrated by referring to a watch or clock. When both hands set out together, at twelve o'clock for instance, the minute hand must travel more

than a whole circle before it will overtake the hour hand, that is, before they will again come into conjunction.

As the star-sphere turns a little more than once around in twenty-four hours, if we observe the heavens, night after night at the same time, we shall notice precisely the same kind of change as when we look at the heavens hour after hour on the same night. If we look at the stars at ten o'clock on any night and note their position, and we again note the position of the stars at eleven o'clock on the same night; then, if afterwards we examine the stars night after night at ten o'clock, we shall find that at the end of about fifteen days they have at this hour the same position that they had on the first night at eleven o'clock —that is, they have advanced by just one hour's motion. In a month or thereabouts, they will be found to have advanced by two hours' motion. In a year they advance by twenty-four hours' motion—that is, by one complete rotation—so that they have resumed their original positions, and this fact explains why, in the course of a year, the star-sphere (in reality the Earth) turns around once oftener than there are days in the year, or 366 times. While during a year the Sun rises 365 times, a star rises 366 times. The latter will therefore during the year have risen at every hour of the day and night.

The late Professor Proctor, in a very instructive article on "How to Learn the Stars," says: "The amount by which the stars have advanced each night on the position they held at the same hour on the preceding night is by no means so small as is, perhaps, commonly imagined. This may be easily tested. Let there be an upright of any sort a few yards to the north of the observer's station, and let him notice the exact hour when a star (at a fair height above the horizon) appears from behind the edge of this upright. At this hour on the next night he will find that, as seen from the same station, the star is about two moon's breadths past the upright's edge. The observer should look through a fixed tube placed in the same position on each night."

The rotation of the Earth determines the length of the day, and may be regarded as one of the most important elements in astronomical science. It serves as a universal measure of time, and forms the standard of comparison for the revolutions of the celestial bodies, for all ages, past and to come. As a recent writer has well remarked, "Theory and observation concur in proving, that among the innumerable vicissitudes that prevail throughout creation, the period of the Earth's diurnal rotation

is immutable." This statement is not strictly correct and needs to be qualified somewhat in the light of some recent discoveries regarding tidal action and its effects in retarding the Earth's rotation, but except from this cause, which is very slow and hardly noticeable in its operation, the length of the sidereal day has not varied as much as the one-hundredth of a second during the last two thousand years. At present we can only say that the change, if any change has occurred since astronomy became an exact science, has been too small to be detected, and as Professor Young remarks, "Probably it has not changed by the one-thousandth part of a second, though of that we can hardly be sure."

Time may be defined as a definite, measured portion of eternal duration, and for many purposes, astronomers find it much more convenient to reckon by the stars than by the Sun. Sidereal time, of course, would not answer for the ordinary affairs of life, since its noon, when the Vernal Equinox is on the meridian, comes at all hours of the night and day at different seasons of the year. We may define this kind of time, at any moment, as the hour-angle of the Vernal Equinox at that moment, and nearly every almanac and text-book on astronomy contains data from which sidereal time and mean solar time may be easily converted into each other.

BATTLE CREEK, Mich.

GREENWICH ASTROGRAPHIC WORK.

WM. W. PAYNE.

Since we have known that the Royal Observatory at Greenwich was to engage with other prominent observatories in the photographic survey of the heavens, we have expected large and helpful results to be the outcome from this source particularly.

It will be remembered that in 1887, was held in Paris, an international congress on Astronomical Photography, at which fifty-six representative astronomers from all parts of the world were present. This first meeting convened by invitation of the French Academy of Sciences, in the month of April of that year, was for the purpose of considering the question of making a photographic map of the heavens by the united effort of many observatories situated in different parts of the world so that all parts of the sky might be photographed under circumstances as favorable as possible.

At that meeting a scheme was approved for this general photographic map that should consist of two sets of photographs each covering two degrees by two degrees on a scale of one millimeter to one minute of arc. One of these photographs was to have an exposure of forty minutes, which was to be used in making the map of the whole sky, commonly called the Astrographic Chart, and the other photograph was to have short exposures of six minutes, three minutes and a supplementary one of twenty seconds, from which a catalogue of reference stars could be made. Each set is taken in duplicate, the centers of one series being at the corners of the other series. A réseau of cross lines five millimeters apart is photographed on each plate to aid in determining the position of stars.

The Astronomer Royal of England was a delegate to the Paris Congress, and at its close he made a report to the Board of Visitors, urging that the Royal Observatory at Greenwich take its share in this scheme which would, in a few years, greatly extend the knowledge of the places of the fixed stars. This important recommendation was supported by such men as Warren de la Rue and Sir William Huggins, and it was soon decided that such coöperative work should be undertaken at Greenwich, and that a suitable photographic telescope for this kind of work should be procured.

Instructions were immediately given to Sir Howard Grubb, as to the details of the new instrument, with directions to proceed at once with its construction.

The new telescope was received in May, 1890, and it was erected in an 18-foot dome which had been before completed for it. During the year following the instrument was brought into working order, but it was kept in the experimental stage until December 1891. While in this condition, among other things, photographs were taken to test the distortion of the object-glass, photometric experiments with various exposures were made with wire and perforated metal screens in front of the object-glass, different photographic plates were tried and the various adjustments of the instrument were perfected.

In December 1891 the regular series of photographs for the Greenwich Zones, extending from 64° north to the Pole were begun, on the plan of photographic exposures already described above.

Volume I. of this Astrographic Catalogue containing a full account of the work done by the Greenwich section of this photographic survey of the sky has just been received. The photo-

graphs taken in the Greenwich Zones have all been made and reduced under the direction of W. H. H. Christie, the Astronomer Royal, and the record so published makes a heavy quarto volume of 738 pages.

In the detail of this work the first thing noticed is the distribution of the photographs for the Astrographic Chart and Catalogue in the part of the sky assigned to Greenwich. Beginning with 65° and 66° in north declination the number of plates used for each was 80, the space covered by each plate being eighteen minutes in right ascension, from center to center. From 67° to 71°, the interval was twenty minutes, and the number of photographs seventy-two. From 71° to 74°, the interval was twenty-four minutes, and the number of photographs were sixty for each of the degrees included. It will readily be seen that when the 90° is reached only one photograph is needed, and by this plan the entire Greenwich Zone would be uniformily covered with equal care.

The amount of work required to secure all these plates in so careful a way that they may be accurately measured later no one can realize who has not had a hand in that kind of astronomical study, long enough to be acquainted with many of the varying and attendant circumstances which the practical astronomer has to face in prosecuting his work. The following table will give some idea of it, in a general way, if we think of it as the limiting numbers of the photographs taken each year in doing the work on the Greenwich Zone:

Year.	Nos.	Year.	Nos.
1890	1— 25	1895	2423—2969
1891	26— 230	1896	2970—3334
1892	231— 717	1897	3335—3808
1893	718—1728	1898	3809—4219
1894	1729—2422	1899	4220—4758

The next important step was the measures of the photographs. After some experimental work, and some discussion of methods and results, systematic work on the measurement of the plates began in October 1894.

What is said here in a few words means greatly more than the ordinary reader will be likely to suppose, because the whole field of this kind of work is very new, and not very easy in kind. The experimental measures of some of the photographs began in 1893, the first being made on photographs of the Pleiades, which showed that the optical distortion was negligible to a distance of sixty minutes from the center of the plate, and very small at the distance of eighty minutes from the center. An account of

this experimental work has already been published in the *Monthly Notices* of the Royal Astronomical Society of England for December 1894.

To hasten the measurement of the plates and to bring together measures of the same star on two overlapping plates a duplex micrometer was arranged by which two such plates could be measured simultaneously. The work began in this way in February 1895, and all measures from this time forward were done in this way.

At the June meeting of the Astrographic Committee at Paris, it was decided to duplicate the measurement of the plates of the Catalogue, the plates being reversed in the micrometer for the second series of measures. The zones that had been measured before this date were 65°, 66° and 67° and parts of 64° and 68°; after this care was taken that the same measurer should do the work in both direct and reversed positions on plates of six-minute and three-minute exposures until June 1896, after which time different persons were employed.

As our readers already know, this work well illustrates a typical method in a new line, it seems helpful to notice the instrument used although it is not a new one. It is, however, one constructed for this particular kind of work, and a general description of it with a frontispiece illustration are therefore given.

The instrument was constructed on the lines laid down by the International Astrographic Congress in 1887, and its general form is shown in the cut just referred to. It has a thirteen-inch photographic telescope and a parallel ten-inch visual guiding telescope in steel tubes firmly connected, mounted equatorially in the German form. The focal lengths of both telescopes are the same, 135.1 inches, so that the scale of a plate placed in the focal plane is one millimeter to one minute of arc, approximately. The photographic telescope is corrected for spherical and chromatic aberration for rays near the Fraunhofer's line G. It is arranged to carry a plate 16 centimeters square, with special provision for each focusing and orientation.

The eye-piece of the ten-inch visual telescope is mounted in cross slides that permits of the observation of a guiding star at a distance of forty-five minutes of arc from the center of the field.

This mounting will allow a motion of the telescope for one and one half hours each side of the meridian without reversing the telescope. Looking at the cut of the telescope one sees that heavy counterpoise is necessary on account of the distance of the two telescopes from the polar axis. Anti-friction rollers and

heavy counterpoises make the movement of the telescopes easy in right ascension. Similar provisions care for the thrust of the polar axis. The driving clock is placed inside the stand and controlled electrically by a seconds' pendulum. The detector of the control is similar in principle to that used in Sir David Gill's form; and the system of connection by differential wheels was devised by Sir Howard Grubb.

The photographs for the Astrographic Chart and Catalogue were all taken with the telescope west of the pier, and in most cases, within one hour of the meridian, the guiding telescope being below the photographic telescope when the instrument is pointing north. The photographs whose measures are given in this volume were all taken between April 2, 1892 and May 28, 1900. The focal adjustment placed the center of the plate somewhat within the focus which was about forty minutes of arc from the center, in order to equalize the definition as far as practicable over the field.

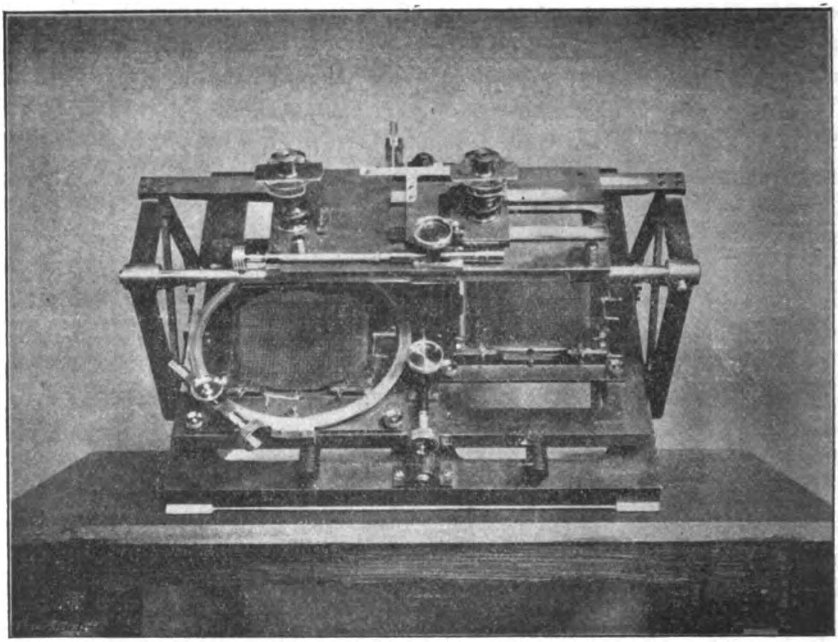
In July 1897 the object-glass was removed and cleaned and replaced without altering the adjustments. During the whole period no alteration was made in the focal adjustment, or, in the tilt of the object-glass, though the latter was verified from time to time. A list of these verifications is given, and a test of the uniformity of the field at different distances from the center is also shown in a satisfactory way.

The method of taking the photographs, the measurement of the photographs and the measurement of diameter and determination of photographic magnitude are other important features of this Catalogue.

The detailed work of choosing the proper kinds of photographic plates, the determination of the réseau as to breadth of lines, size of square, and method of impression on the film are all instructive reading for those who are interested in the practical details of this work.

As we come to the measurement of the photograph the duplex micrometer with the glass diaphragm claims interested attention. A cut of this is herewith presented. This micrometer was brought into use in January 1895, and with it nearly all the measures for the Catalogue were made. The essential feature of the instrument is that two different plates on which the same portion of the sky is photographed are viewed and measured at once. "The plates are placed in a frame movable in the direction of the y co-ordinate, and the carrier of one of the plates can be adjusted so that the images of the same star on the two plates

are very approximately on the same horizontal line. Two microscopes carried on a horizontal slide move perpendicularly to the direction in which the frame moves, and their distance apart can be readily adjusted so that when the image of a star on one plate is at the center of the field of one microscope the image of the same star on the second plate is at, or very near, the center of the field of the second microscope." The various working parts of the instrument will be easily understood.



DUPLEX MICROMETER.

The glass diaphragm with its two scales at right angles are so divided that one interval corresponds to one hundredth of a réseau interval of three seconds of arc. The star's image is placed accurately at the intersection of the two scales, and the position of the réseau lines relative to it is read off on the scales by estimation to one thousandth part of a réseau interval, which means in the sky three-tenths of a second of arc.

From what has already been said, it has been noticed that the arrangement of measures adapted for this work is such that the sky is divided into zones in declination one degree wide, and the measures of the same star on overlapping portions of two plates are given side by side. It is plain that the work of measurement

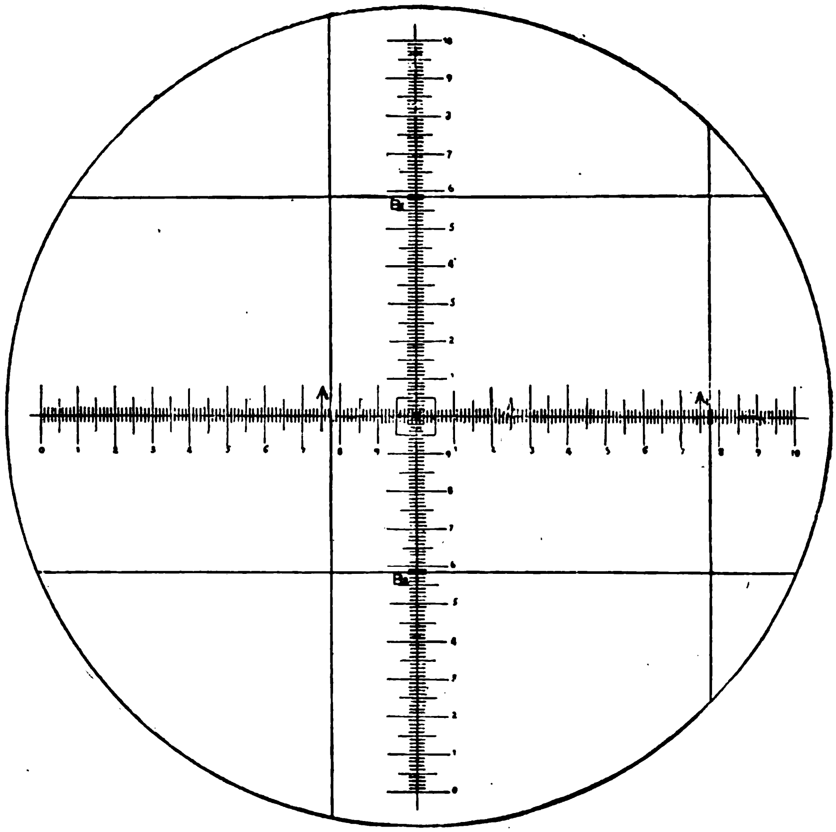


Diagram of Glass Diaphragm.

by the aid of the duplex micrometer would be considerably hastened. The following cuts show approximately how the

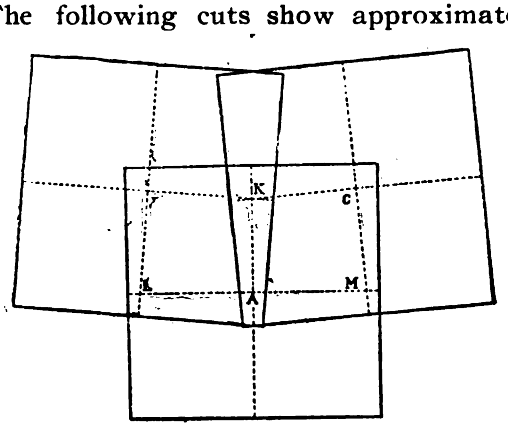


Diagram 1.

plates were arranged in this overlapping process. For example a star near the center of A would also be shown on the right hand bottom corner of B, the left hand bottom corner of C, and on the top right and left hand corners respectively of two plates in a lower zone. In Diagram I., A, B, C, are the centers of the three plates A K, L A M, B L, B K, and C M, C K, are the central réseau lines. A K, B L, and C M, are the projections of the meridians.

In Diagram II., the division of the sky is shown. A, B, C, K, L, M, correspond to the same letters in Diagram I. D is the center of the adjacent plates in the same zone as A, E in the center of the third plate in the same zone as C and B.

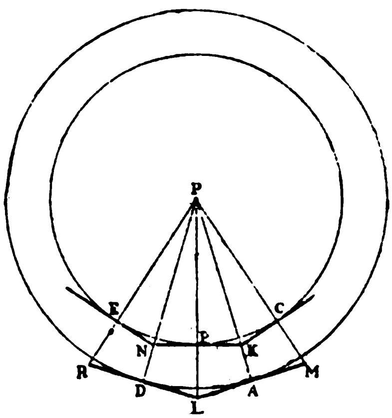


DIAGRAM II.

The plan of measuring the plates is of course a very important feature of the work. Each plate is measured in two positions the second being when the plate is turned through 180° giving a direct and reversed position with careful independent readings in each. "The readings on the glass scale of the two réseau lines between which the stars are contained are given in the same horizontal line, the measures of three-minute images are placed below those of the six-minute images. The mean includes the correction for *runs*, and is formed by applying the proportional part of the difference of the readings of the réseau lines on the two sides of the glass scale." In this way a weighted mean is at once found from the measures, the unit of measure is simple and the diameters of the star images are quickly and reliably found. The specimen page of the measuring book is interesting in these particulars.

The last point that we can notice in the hasty examination of this volume is the determination of the photographic magnitudes of the stars whose images are found on the photographic plates. We have spoken of the way in which the measures of the star-images on the photographic plates were made, indicating that the result in every case was the mean of the two measures at least. The unit employed in the printed results is one two-thousandths of the réseau interval or fifteen hundredths of a second of arc. If this value is unity, then four would be six-

tenths of a second of arc, and ten would be one and one half seconds of arc and so on; the diameters thus being expressed as integers.

No difficulty presents itself in thus measuring fairly bright stars near the center of the plate. At a distance of forty minutes from the center the star images begin to be sensibly elongated in the radial direction, so it was necessary to take the mean of the horizontal and vertical diameters and set down this as an equivalent of a circular diameter. In the case of the faint star-images on the plates, "The actual diameter may be the same as that of a somewhat brighter star, but the image is gray and not black. Allowance is made by the measures for the want of density in the images, and also for the shading off at the edge, and the diameter set down is that of an equivalent black image, *i. e.* one which would contain the same amount of silver deposit. In all measures made since 1897, great care has been taken to secure uniformity in these estimates, but in the measures before this date, *i. e.* in the direct position between Dec. + 64° and + 68°, the diameters of the very faint stars have not been reduced sufficiently to make them strictly comparable with those brighter stars having black images."

When the best measures for the photographic images of the faint stars on the plates have been secured, the next step is to relate these results to the standard photometric measures in units of star magnitude. In this work the photometric scale used is given by Professor Pickering in the Harvard Annals of faint stars near certain variables which lie in the Greenwich zones. Other aids of photometry are also used in making needed comparisons for the sake of converting the photographic measures of star images into stellar magnitudes consistent with the standard scale of photometry. This must be done by finding some empirical law connecting the two. The formula expressing this relation is worked out in an article in the *Monthly Notices* of the Royal Astronomical Society, Vol. 53, pp. 125-146, and is as follows, m equaling magnitude, d, measured diameter, C and n being constants:—

$$m = C - n\sqrt{d}$$

We have been unusually full in regard to some of the details of this interesting volume of modern method, mainly because the methods are new, and we are sure that the amateurs and astronomers on this side of the sea will be as much interested as we can be, to know something of the details of how these things are done by experts elsewhere.

The remainder of the volume is generally in the line of methods that do not need special reference.

American astronomers engaged in any way in astrographic work will have a library in itself if they are fortunate enough to become possessors of the entire catalogue and charts that finally will make up the whole survey of the heavens. We very much hope that Goodsell Observatory will be able to secure the volumes embracing the entire catalogue and the charts that will cover the Greenwich zones if we are unable to possess the parts to be obtained from the sources.

COMMON'S 60-INCH TELESCOPE.

EDWARD C. PICKERING.

An important part of the work of the Harvard College Observatory for the last quarter of a century, and of the writer personally, has been the determination of the light of the stars. About one hundred thousand measures of four thousand stars, including all those visible to the naked eye in Cambridge, and all those of the sixth magnitude and brighter, north of declination — 30°, were made in 1879 to 1881. The telescope used in this work had an aperture of only two inches. A similar instrument, with an aperture of four inches, has been in use here and in Arequipa, since 1882. More than a million settings, on nearly sixty thousand stars, in all parts of the sky from the North to the South Pole, have been made with it. Numerous standards of the tenth magnitude and brighter are thus provided. In 1899, a telescope of twelve inches aperture was mounted horizontally, and used in a similar manner. Since then, four hundred thousand measures of about eleven thousand stars have been made, thus furnishing standards of the twelfth magnitude and brighter.

As this Observatory has not heretofore owned a very large telescope, we have had to rely on the courtesy of our friends for measures of the fainter stars. By means of an appropriation from the Rumford Committee, and with the coöperation of the Directors of the Yerkes, Lick, McCormick, and Halsted Observatories, several of the largest telescopes in the world have taken part in a determination of standard magnitudes of very faint stars. A request for a telescope of the largest size, to be mounted at Harvard, has not hitherto been made, since the atmospheric conditions in the eastern part of the United States and in Europe

are not so favorable to the best work as in certain selected stations in the tropics. By a modification of the twelve-inch telescope described above, good measures can be made of the stars, even if their images are bad. By reducing the image of the real star, instead of that of the artificial star, more accurate measures may be made, certain sources of constant error eliminated, and since both images are faint when compared, defects in them are rendered imperceptible. In this way, even so large an object as the planet Mars has been satisfactorily compared with an artificial star.

A reflecting telescope of sixty inches aperture was constructed by the late A. A. Common, and for several years has been idle. From its great aperture it should show extremely faint stars, and would be especially adapted to measuring their light. Some years ago, an attempt was made to purchase this telescope, but the means of the Observatory would not then permit. In 1902, the anonymous gift of $20,000 was received, and it has supplied several urgent needs of the Observatory. Representing these facts to Professor Turner of Oxford, during his recent visit to Harvard, he recognized the importance of utilizing so valuable an instrument, and that the nature of the observations and other conditions were favorable to securing valuable results. He therefore wrote to Mr. T. A. Common, with the result that this Observatory has purchased the telescope on such liberal terms that Mr. Common may fairly be regarded as having contributed a large portion of the cost.

Steps are being taken for packing and transferring the instrument at once to Cambridge. It is hoped that in a few weeks the telescope may be received and mounted, and that observations to supply one of the great wants of Astronomy, a measure of the light of the very faint stars, can then begin. The work of many years has supplied this want for the brighter stars, and may now be extended to the faintest objects within the reach of human knowledge.

We have here another illustration of the valuable results which may be obtained in Astronomy, from a combination of favorable circumstances. It is still another result of the utmost importance derived from a gift made without restrictions. It affords an opportunity to make useful the greatest work of one of the most successful of the makers of large telescopes. It secures the liberal aid of his family through the friendly assistance of a brother astronomer. All have been brought together through a form of investigation which appears especially suited

to these particular conditions.
HARVARD COLLEGE OBSERVATORY,
Circular No. 83, August 18, 1904.

VARIATION OF LATITUDE.

WM. W. PAYNE.

An intelligent reader of this journal recently asked if there is anything new in regard to the variation of latitude which might be of service to him in speaking of this modern astronomical discovery in a public address, now in the course of preparation.

In answering this query we have thought that it might interest our readers generally if we gave a very brief review of the steps by which astronomy came into possession of this important discovery, as well as to point out some of the more significant consequences likely to follow in regard to the physics of the Earth as a whole.

Since the latitude of any place on the Earth's surface is the distance of it from the equator either north or south, it is evident that the latitude of all places would be constant, or without change in long periods of time, if the equator itself has a fixed and unvarying position constantly on the surface of the Earth. But this imaginary line which we call the Earth's equator is a line measuring the circumference of the Earth everywhere ninety degrees from two points called the geographic poles of the Earth. These poles of the Earth are the ends of the axis of the daily rotation of the Earth. Now it is evident that if this imaginary line within the Earth, which we call its axis of daily rotation, has uniformly a constant place in the spheroid, then the points on the surface called poles will not change, the equator can not change and the latitude of places on the Earth's surface will not change as long as the first named condition prevails. But it this axis of rotation changes its place within the Earth it is probable that such a change will be made to keep the rotation symmetrical in regard to mass. In view of the great mass of the Earth, its rapid rotation; and, as the mathematician would say, its very large moment of rotational energy, one can easily imagine what a tremendous force would be required to change the plane of rotation, or to make the Earth rotate unsymmetrically. These things direct the physicist's study, at once, to the interior structure of the Earth. They have also given a challenge to the astronomer to tell if he can, whether or not the

Earth is rotating about one fixed axis of symmetry as time goes on indefinitely.

The fact that the poles of the Earth may change their places on the surface of the Earth within very narrow limits has been thought of long ago. Euler about the middle of the eighteenth century, or a little later, investigated what would be the effect of such movements if they should take place. As Turner has pointed out in his "Modern Astronomy," page 199: "He found that a rigid body like the Earth, which was spinning about on an axis once a day with nearly complete steadiness, might have a slight 'wabble' which would mean that the north pole was in motion, but that, if so, the motion would complete a circuit every ten months. There seemed to be no doubt about this result, and astronomers examined their observations of latitude to see whether there was any change of ten months period. *None was found*, although long series of observations were cut up into chapters of ten months and added together to magnify any small disturbance; and after several attempts of this kind, the question was regarded as settled in the negative. The north pole did not move at all. So confident did astronomers become on this point that when Mr. Chandler, who ultimately demonstrated the real facts so clearly, found an apparent movement of the pole by observation with the Almucantar in 1885, he himself thought he must have made some mistake, and did not follow up the matter."

The instrument with which Dr. Chandler made this observation was one of his own planning and radically different from similar ones of its kind. We have repeatedly spoken of the Almucantar in this publication at other times.

Not long after Dr. Chandler's observations were made, Dr. Küstner of Berlin published his own made about the same time which also indicated a motion of the north pole. This fact was a fortunate one just at this time for general attention was called to this singular coincidence, and interest was awakened on account of it. There were two ways of study of this important problem. One was to make a series of observations in future years adapted to the problem in hand and then find the result from them. The other was to make a study of observations already made in the past and determine the motion of the pole in that way. German astronomers chose the former method and Dr. Chandler of America selected the latter, feeling sure that if the supposed motion of the pole was real it ought to be plainly revealed in observations that have been made and published, as well as in those

that should be made in the future.

The observations of the past had been examined for this purpose, but the real question was, had those observations been worked out as thoroughly as as they could and should be. Euler's' limit of ten months might not be the whole truth. Chandler said "let us give up this limitation, and see whether or not the observations perhaps indicate some other period. Very soon after work began on this plan Dr. Chandler was able to say with certainty that the period was fourteen months instead of ten.

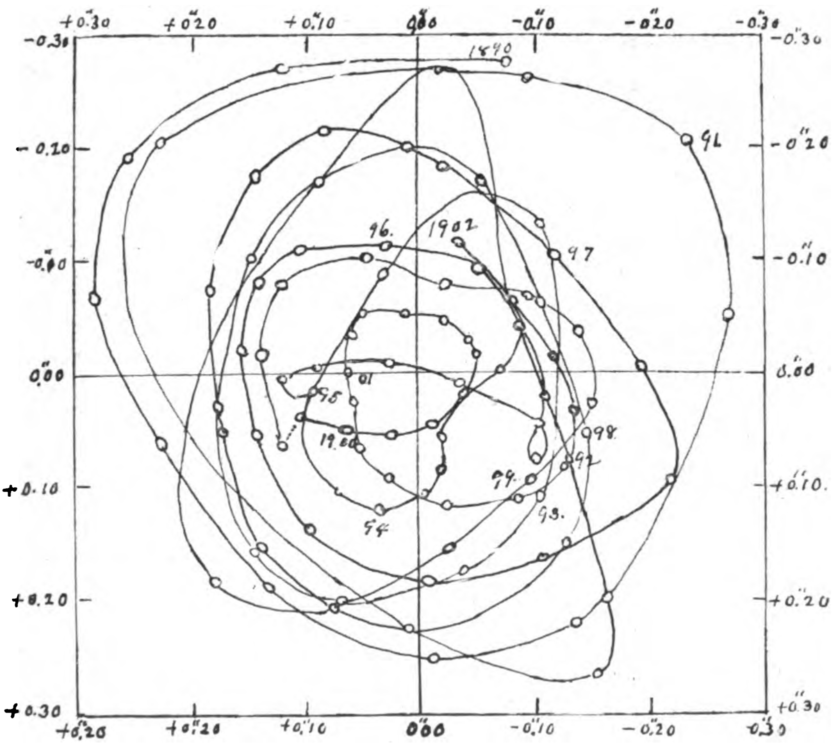
Then followed one of those lively discussions in which one mathematician stands alone with the world of that science against him. The great Euler had said, from a rigid analysis by mathematics, that if such motion of the pole should take place, the period would be ten months. No one could dispute Euler's mathematics. The ablest scholars said so, and told Chandler he must have made some mistake somewhere or somehow in his work. Chandler's reply was heroic and worthy of the metal that great men are made of. He answered in effect that he did not care for Euler's mathematics, the observations plainly showed his result of a fourteen months' period. If Euler said ten months he must be wrong. As Professor Turner of England has tersely said, "It was a dead-lock: Chandler and observation against the whole weight of astronomical opinion and theory." About this juncture of the battle Professor Simon Newcomb of Washington, one of America's brilliant lights in mathematics and astronomy began to look into the problem carefully, and it occurred to him that possibly Euler had made some mistake in assuming, as a condition in the problem that the Earth was a *rigid body*, and possibly, in this direction, lay the discrepancy between theory and observation, Chandler still firmly holding that observation must always decide upon the probability of theory. Not long after this Professor Newcomb and some prominent physicists took the position that the Earth is not a rigid body, and that when allowance is made for the yielding of its stiff mass to stress, ten months' period in its wabble is a minimum period, which may be increased more and more according to the plastic quality of the Earth's mass. Chandler won. His period of fourteen months was the correct one, and his noble discovery brought to science more than he himself anticipated in giving it some data by which to measure the plasticity of the Earth.

The movement of the pole on the surface of the Earth is small,

not greater than about thirty feet from a mean position at any time, so that astronomers do not feel that any serious consequences can come to the common order of things by the change of latitude due to these physical facts.

An illustration of the motion of the north pole for a period from 1890 to 1902 is given herewith, which shows the nature of its periodic motion. Dr. Chandler's view of it is that the movement of the pole is composed of two motions, one *annual* revolution in an ellipse about thirty feet long, but varying in width of position, and the other a revolution in a circle about twenty-six feet in diameter having *a period of about* 428 days which is the fourteen months' period already mentioned.

The accompanying cut is a copy of Professor Th. Albrecht's drawings found in his papers concerning the results of interna-



MOTION OF THE NORTH POLE BETWEEN 1890 AND 1902.

tional latitude work up to the year 1902. The latest of these papers which we have seen was published in 1903 at Berlin, Germany. In this cut it is necessary to combine two drawings

which were easily traced because both were drawn to the same scale.

EXPLOSION OF STARS.*

PROFESSOR A. W. BICKERTON.

Do stars explode? Are the observers of Lick and Yerkes correct when they said that Nova Persei had become a nebula that was expanding at such a rate that no theory of its origin was tenable, but that a star had exploded, been converted into gas, and blown at a velocity of thousands of miles a second to spread itself throughout the entire universe?

Is it conceivable, with the known laws of matter and energy, that a force can be generated great enough to blow a star to pieces? A calculation shows that were the entire star an explosive, it would have to be a score of thousands of times stronger than dynamite. Is there in Nature anything in which such a store of energy exists? This question must undoubtedly be answered in the affirmative, and the source of the energy is the attractive force of gravitation. The force with which the Sun attracts matter, and the enormous distance through which this force extends, gives us an energy so great that, without any original motion, a particle falling from the nearest star upon the Sun would reach it with a velocity of three hundred and ninety miles a second. This velocity would possess an energy hundreds of millions of times greater than that of an express train, and the temperature produced by the stoppage of the motion would excel that of an electric furnace a score of thousands of times.

Hence, in the collision of suns we have an agent that may generate energy sufficient to cause the Sun to explode, but so enormous is the mass of a Sun, that the energy of collision has been shown to be too small to blow the Sun into a nebula; but the probabilities of a direct complete collision between suns is small indeed. Any original motion or any attraction of other bodies acting during their fall towards one another, would tend to make the impact of a tangential character, and it is upon the study of tangential impact that the solution of our problem depends. The velocity with which two suns would sweep past one another would be so great that a slight graze would not stop them. They would fly past one another, scarred by the encounter; but

* *Knowledge and Scientific News*, Nov. 1904.

the portions that lay in one another's path, and that did actually come into collision would be swept from the remainder, would coalesce, and would form a new body in space. The tremendous motion would be converted into heat, and the mass of the new body, if the graze were not deep, might be so small that the explosive pressure produced would blow it into a nebula that would continue to expand with an enormous velocity, and every particle be finally dissipated into free space; in some cases leaving the very universe itself.

It is thus seen that the numbers and distribution of the stars must, on the demonstrated laws of Nature, produce an explosion; and it is highly probable that all the so-called temporary stars that have appeared at intervals in the heavens, usually increasing in brilliancy for some hours, or a day or two, and then gradually disappearing, are caused by partial impacts of stars or, in most cases, of dead suns. For all these bodies have similar spectra crossed with double lines, the one showing recession, and the other approach, indicating the two scarred suns that have struck one another; whilst the brilliant continuous spectrum seen in all new stars, for some time after the outbreak, is due to the mass of flaming gas that must expand at the rate of some millions of miles an hour.

The velocity with which these bodies pass one another would cause the impact to be over in an hour or less; and in this time a body is produced with a higher temperature than that of any ordinary star. This brilliant body would soon expand until the globe of fire would be thousands of times the volume of the Sun.

Hence we need not be surprised that Tycho Brahe's new star grew to be more brilliant than Jupiter, even more brilliant than Venus at quadrature; so intense, in fact, as to be visible at noonday. Nor need we wonder at its disappearance, for the flight of its myriad molecules all travelling from the point where the explosion occurred, would rapidly tend in their radial outrush to become parallel, and the molecules consequently cease to strike one another save at intervals; and as molecules only radiate immediately after encounters, it is obvious that, as these encounters become fewer in number, the luminosity of the mass would lessen and go on lessening until it was absolutely lost to vision.

Herschel has told us that the only possible explanation of the character of the many planetary nebula that he discovered was that they were hollow shells of gas. Every stellar explosion that is produced by a partial impact must result, at one stage of

its history, in a planetary nebula that may be permanent or evanescent according to the attractive power of the new body as compared with its temperature.

Thus evanescent planetary nebulæ would be produced bv slight grazes, whereas a deeper graze might produce a permanent planetary nebula, and still deeper grazes result in a large ratio of the molecules being attracted back, and producing a star in the center of the nebula. Examples of this are comparatively numerous in the celestial vault.

So that our observers were doubtless right in the conclusion they came to that "Nova Persei" was a celestial explosion in which a star had been blown to pieces. And this fragment of the study of impact shows how important an agent impact is in astronomical evolution, for it must be remembered that all kinds of impacts may take place, from a mere graze up to a complete impact. Impacts may take place between dead suns or lucid stars. They may take place between meteoric swarms, or be tween star clusters. The impact of nebulæ may range from a mere graze through deep cuts, up to entire coalescence; and every form of impact save direct center to center must result in rotation, and obviously furnishes an explanation of the spiral character of so many thousands of nebulæ. Again, such vast bodies as the two magellanic clouds may be approaching one another, and after countless ages may impact, and should they strike deep enough into one another, coalescence of a whirling character would result, giving a galaxy of stars of a double spiral character, and spreading the poles of the ring with masses of nebulous matter, a configuration that exactly corresponds with the structure of our universe, and hence may we not ask the question, "Is not our visible universe a result of the coalescent impact of two previously existing universes, and if so may not such cosmic systems exist in endless number throughout the infinity of space?"

Such are the lofty conceptions that develop themselves from the study of impact, carried fearlessly to its legitimate conclusions.

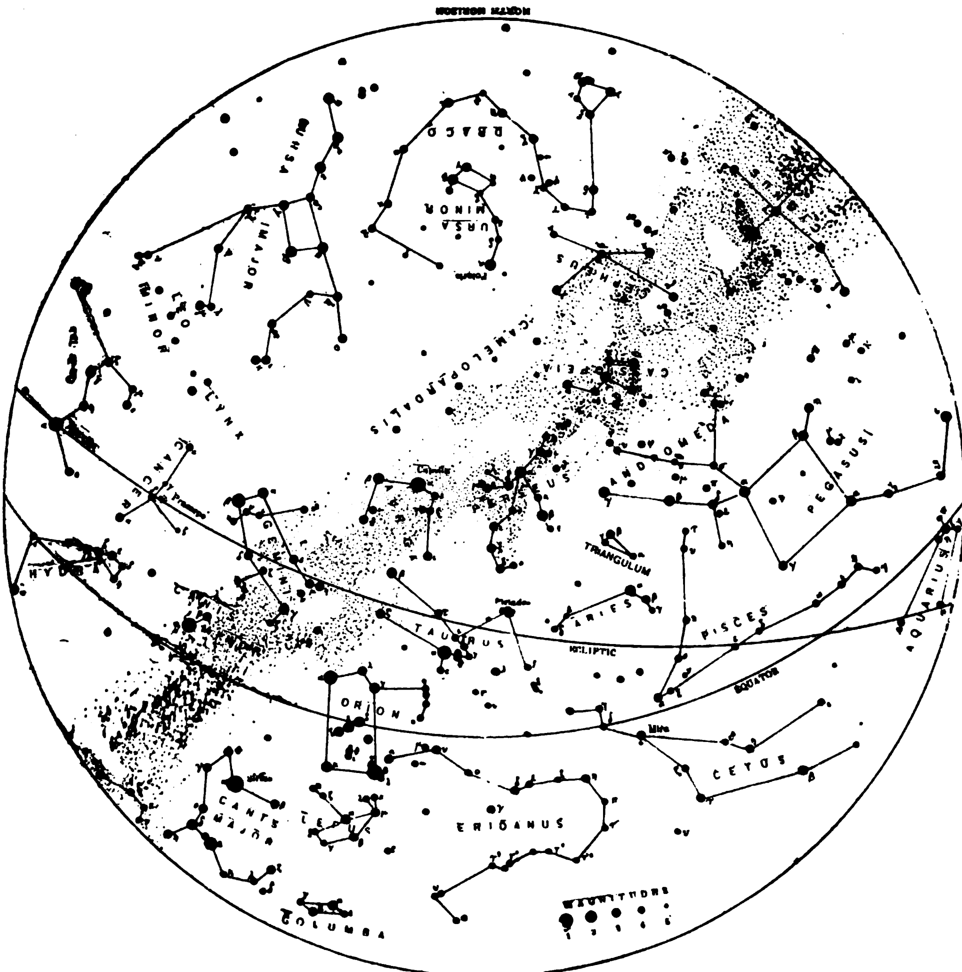
PLANET NOTES FOR JANUARY, 1905.

H. C. WILSON.

Mercury will be morning star during this month, and will be at greatest elongation, west from the Sun 24° 29′ on January 22. The brightness of the planet then will be only 39 as compared with its maximum of 71. On the

morning of January 14 Mercury and Uranus will be in conjunction, Uranus being 2° 46′ south of Mercury.

Venus is ascending the slope of the ecliptic and toward the end of the month will be close to the equator and well out from the Sun, so that observing conditions, except for the winter temperature are good. The disk is two-thirds



THE CONSTELLATIONS AT 9 P. M. JANUARY 1, 1905.

lighted and the brilliancy, now about half of that at maximum is rapidly increasing. Venus and the crescent Moon will be in conjunction on the morning of January 9 at 9 o'clock, C. S. T., the Moon passing 2° 12′ to the north of Venus.

Mars will be at quadrature, 90° west from the Sun, January 26. The disk of the planet on Jan. 1 will be between 6″ and 7″ in diameter and will be nine-

tenths illuminated. Its brilliancy then will be 4 as compared with a maximum, for the year 1905, of 37.

Jupiter will be at quadrature, 90° east from the Sun, January 11. No doubt during the past two or three months many of our readers have been watching the changes in the appearance of the belts of this splendid planet as its swift rotation has brought different parts into view night after night. The great red spot of years ago is no longer visible, but the place where it was is marked by the great indentation which it produced in the prominent south temperate belt, showing that there is something of permanence in its character, although its red color has long ago faded out.

Saturn will set too soon after the Sun to be observed during this month.

Uranus is behind the Sun and cannot be observed during this month.

Neptune is just past opposition, and so is in best position for the year. Its position January 1 will be R. A. $6^h\ 28^m\ 53^s$, Decl. + 22° 15′ and February 1, R. A. $6^h\ 25^m\ 25^s$, Decl. + 22° 18′.

PHENOMENA OF JUPITER'S SATELLITES.

1905 [Central Standard Time].

1905	h	m		
Jan. 2	8	50	P. M.	III Oc. Dis.
	10	08	"	I Oc. Dis.
	11	03	"	III Oc. Re.
3	7	17	"	I Tr. In.
	8	37	"	I Sh. In.
	9	30	"	I Tr. Eg.
	10	49	"	I Sh. Eg.
4	4	36	"	I Oc. Dis.
	8	07	"	I Ec. Re.
5	5	18	"	I Sh. Eg.
	8	23	"	II Oc. Dis.
	10	55	"	II Oc. Re.
	11	07	"	II Ec. Dis.
6	4	29	"	III Sh. In.
	6	19	"	III Sh. Eg.
7	6	02	"	II Tr. Eg.
	6	14	"	II Sh. In.
	8	43	"	II Sh. Eg.
10	9	11	"	I Tr. In.
	10	32	"	I Sh. In.
	11	34	"	I Tr. Eg.
11	6	32	"	I Oc. Dis.
	10	03	"	I Ec. Re.
12	5	01	"	I Sh. In.
	6	54	"	I Tr. Eg.
	7	14	"	I Sh. Eg.
	10	58	"	II Oc. Dis.
13	4	32	"	I Ec. Re.
	5	06	"	III Tr. Eg.
	8	31	"	III Sh. In.
	10	20	"	III Sh. Eg.
Jan. 14	6	08	P. M.	II Tr. In.
	8	40	"	II Tr. Eg.
	8	52	"	II Sh. In.
	11	21	"	II Sh. Eg.
16	5	27	"	II Ec. Re.
18	8	28	"	I Oc. Dis.
19	5	36	"	I Tr. In.
	6	57	"	I Sh. In.
	7	50	"	I Tr. Eg.
	9	09	"	I Sh. Eg.
20	6	28	"	I Ec. Re.
	6	57	"	III Tr. In.
	9	13	"	III Tr. Eg.
21	8	47	"	II Tr. In.
	11	20	"	II Tr. Eg.
23	5	29	"	II Oc. Re.
	5	40	"	II Ec. Dis.
	8	03	"	II Ec. Re.
26	7	34	"	I Tr. In.
	8	53	"	I Sh. In.
	9	47	"	I Tr. Eg.
27	4	55	"	I Oc. Dis.
	8	24	"	I Ec. Re.
28	4	16	"	I Tr. Eg.
	5	34	"	I Sh. Eg.
30	5	38	"	II Oc. Dis.
	8	11	"	II Oc. Re.
	8	18	"	II Ec. Dis.
	10	42	"	II Ec. Re.
31	6	43	"	III Ec. Dis.
	8	14	"	III Ec. Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

The Moon.

Phases.			Rises. (Central Standard Time at Northfield. Local Time 13m less.)	Sets.
1905			h m	h m
Jan.	5	New Moon	7 25 A. M.	5 09 P. M.
	13	First Quarter	11 47 P. M.	1 0 A. M.
	20-21	Full Moon	4 49 "	7 43 "
	27	Last Quarter	12 02 A. M.	11 22 "

Occultations Visible at Washington.

Date. 1905.		Star's Name.	Magni-tude.	IMMERSION. Washing-ton M.T.		IMMERSION. Angle f'm N pt.	EMERSION. Washing-ton M. T.		EMERSION. Angle f'm N pt.	Dura-tion.	
				h	m	°	h	m	°	h	m
Jan.	2	B. A. C. 5712	6.5	16	20	122	17	15	265	0	55
	9	B. A. C. 7919	6.5	8	36	83	9	34	237	0	58
	10	Mayer 997	6.4	9	02	59	10	02	260	1	00
	14	B. A. C. 764	6.3	6	23	116	7	21	195	0	58
	16	D. M. + 14° 657	5.9	4	42	85	5	55	238	1	13
	16	γ Tauri	3.9	12	55	152	13	20	197	0	25
	18	D. M. + 17° 1182	5.7	14	35	163	15	00	208	0	25
	19	D. M. + 17° 1479	6.2	8	00	140	8	46	217	0	46
	20	B. A. C. 2649	6.0	6	14	111	7	09	252	0	55
	20	5 Cancri	5.9	7	35	119	8	35	247	1	00
	22	A Leonis	4.6	11	46	125	13	00	274	1	14
	23	*c* Leonis	5.1	9	29	135	10	22	258	0	53
	25	*k* Virginis	5.7	13	27	138	14	33	273	1	06
	28	B. A. C. 5188	6.5	13	03	117	13	59	278	0	56
	29	24 Scorpii	5.0	14	55	190	15	01	201	0	06

COMET AND ASTEROID NOTES.

Ephemeris of Comet Tempel₂ (1873 II).

1904		α app.			δ app.			log Δ	Aber.		$1{:}r^2\Delta^2$
		h	m	s	°	′	″		m	s	
Dec.	1	19	41	27.6	—24	45	36	0.28871	16	9	
	2		45	13.0	24	42	51	28981		12	
	3		48	58.1	24	39	44	29092		14	
	4		52	42.9	24	36	15	29205		17	0.131
	5	19	56	27.4	24	32	25	29319		19	
	6	20	0	11.5	24	28	14	29435		22	
	7		3	55.2	24	23	41	29552		24	
	8		7	38.5	24	18	48	29671		27	0.126
	9		11	21.3	24	13	34	29791		30	
	10		15	3.6	24	8	0	29913		33	
	11		18	45.3	24	2	5	30036		35	
	12		22	26.4	23	55	51	30161		38	0.122
	13		26	6.9	23	49	17	30286		41	
	14		29	46 8	23	42	24	30414		44	
	15		33	26.0	23	35	12	30542		47	
	16		37	4.4	23	27	41	30672		50	0.117
	17		40	42.1	23	19	52	30804		53	
	18		44	19.1	23	11	44	30936		56	
	19		47	55.2	23	3	19	31070	16	59	
	20		51	30.5	22	54	37	31206	17	3	0.113
	21		55	5.0	22	45	37	31342		6	
	22	20	58	38.7	22	36	21	31480		9	
	23	21	2	11.4	—22	26	49	0.31619	17	12	

EPHEMERIS OF COMET TEMPEL$_2$ (1873 II).—Continued.

1904		α app.			δ app.			log. Δ	Aber.		$1:r^2\Delta^2$
		h	m	s	°	′	″		m	s	
Dec.	24	21	5	43.3	−22	17	0	31760	17	16	0.108
	25		9	14.2	22	6	56	31901		19	
	26		12	44.2	21	56	36	32044		22	
	27		16	13.3	21	46	2	32188		26	
	28		19	41.4	21	35	12	32333		29	0.103
	29		23	8 5	21	24	9	32479		33	
	30		26	34.7	21	12	52	32626		37	
	31		29	59.8	21	1	21	32775		40	
	32	21	33	24.0	−20	49	37	0.32924	17	44	0.098

Ephemeris of Comet *a* 1904 (Brooks)—The following ephemeris is a continuation of that given by A. A. Nijland in *Astr. Nachr.* Nos. 3952 and 3963, and has been computed by H. L. Rice of the U. S. Naval Observatory. The parabolic elements adopted by Nijland are published by him in *A. N.* No. 3952.

The brilliancy of the comet remains practically constant from Oct. 10 to the end of the year, soon after which it will begin to diminish quite rapidly. Observations made with the 26-inch equatorial at the U. S. Naval Observatory, about the middle of October, indicate that good observations of this object might readily be made with the larger instruments during November and December.

EPHEMERIS OF COMET *a* 1904.

G. M. T.		α			δ		log Δ	Br.
1904		h	m	s	°	′		
Oct.	30.5	12	36	56	+ 43	47.3	0.5999	0.18
Nov.	1.5		37	22	43	58.3	.5986	.18
	3.5		37	46	44	10.2	.5973	.18
	5.5		38	07	44	22.9	.5959	.18
	7.5		38	26	44	36.5	.5945	.18
	9.5		38	42	44	51.0	.5930	.18
	11.5		38	55	45	6.4	.5915	.18
	13.5		39	5	45	22.7	.5899	.18
	15.5		39	11	45	40 0	.5883	.18
	17.5		39	13	45	58.2	.5866	.18
	19.5		39	12	46	17.3	.5049	.18
	21.5		39	7	46	37 2	.5832	.18
	23.5		38	57	46	58.0	.5814	.18
	25.5		38	43	47	19.7	.5796	.18
	27.5		38	23	47	42.3	.5778	.18
	29.5		37	58	48	5.8	.5760	.18
Dec.	1.5		37	27	48	30.2	.5742	.18
	3.5		36	50	48	55.5	.5724	.18
	5.5		36	7	49	21.7	.5705	.18
	7.5		35	17	49	48.7	.5687	.18
	9.5		34	20	50	16.6	.5669	.18
	11.5		33	15	50	45.2	.5651	.18
	13.5		32	1	51	14.5	.5634	.18
	15.5		30	39	51	44.5	.5617	.18
	17.5		29	8	52	15.2	.5601	.18
	19.5		27	27	52	46.5	.5586	.18
	21.5	12	25	37	+ 53	18.3	0.5571	0.18

Comparison with an observation made here Oct. 17 gives as corrections to the ephemeris: $\Delta\alpha = -2^s$, $\Delta\delta = -0'.4$.

Mr. E. I. Yowell, of the Naval Observatory, is making a definitive determina-

tion of the orbit of Comet α 1904 (Brooks), and requests that all yet unpublished observations of it be printed as soon as possible.

The Astronomical Journal.—Supplement to 568.

Ephemeris of Encke's Comet.

(For Berlin Noon continued from page 489.)

1904		α app.			δ app.		log r	log Δ	Aber.	
		h	m	s	°	′			h	m
Oct.	14	0	38	46	+ 28	14.5	0.2248	9.8521	5	55
	15		35	3	28	12.0	2215	8452		50
	16		31	15	28	8.5	2183	8383		44
	17		27	20	28	4.1	2150	8315		39
	18		23	20	27	58.7	2116	8248		33
	19		19	15	27	52.5	2082	8182		28
	20		15	4	27	45.2	2048	8117		23
	21		10	48	27	36.9	2013	8054		19
	22		6	28	27	27.7	1977	7993		14
	23	0	2	3	27	17.3	1941	7932		10
	24	23	57	34	27	5.7	1905	7872		5
	25		53	2	26	53.1	1868	7815	5	2
	26		48	27	26	39.4	1831	7759	4	58
	27		43	49	26	24.4	1793	7706		55
	28		39	8	26	8.2	1754	7654		51
	29		34	25	25	51.1	1714	7604		48
	30		29	41	25	33.1	1675	7555		44
	31		24	55	25	13.7	1635	7507		41
Nov.	1		20	8	24	53.1	1594	7461		38
	2		15	21	24	31.5	1552	7420		35
	3		10	34	24	8.6	1510	7380		33
	4		5	48	23	45.1	1467	7342		30
	5	23	1	3	23	20.6	1424	7305		28
	6	22	56	19	22	55.1	1380	7270		25
	7		51	37	22	28.7	1335	7237		24
	8		46	57	22	1.5	1289	7207		22
	9		42	19	21	33.5	1243	7178		20
	10		37	44	21	5.0	1195	7151		18
	11		33	11	20	35.6	1147	7125		17
	12		28	42	20	5.8	1098	7102		16
	13		24	17	19	35.3	1048	7080		15
	14		19	54	19	4.5	0997	7059		13
	15		15	34	18	33.0	0946	7040		12
	16		11	18	18	1.2	0893	7023		11
	17		7	5	17	29.0	0840	7008		10
	18	22	2	56	16	56.4	0785	6993		10
	19	21	58	49	16	23.7	0730	6978		9
	20		54	47	15	50.9	0673	6965		8
	21		50	47	15	17.8	0615	6953		7
	22		46	49	14	44.3	0555	6942		7
	23		42	54	14	10.6	0495	6931		6
	24		39	4	13	37.1	0433	6921		6
	25		35	17	13	3.6	0371	6912		5
	26		31	31	12	29.7	0307	6904		5
	27		27	47	11	55.5	0242	6896		4
	28		24	3	11	21.3	0175	6888		4
	29		20	21	10	46.9	0106	6880		3
	30		16	40	10	12.3	0.0036	6874		3
Dec.	1		13	0	9	37.5	9.9964	6868		2
	2		9	20	9	2.4	9891	6862		2
	3		5	40	8	27.0	9815	6855		2
	4	21	2	0	7	51.3	9738	6849		2
	5	20	58	21	+ 7	15.4	9.9659	9.6843	4	1

New Asteroids.—The following have been added to the list of new minor planets since our last note:

	Discovered by	at	Local Mean Time.		h m	R. A. h m	Decl. ° ′	Mag.
1904 OY	Götz	Heidelberg	1904 Oct.	3	9 54.8	1 00.4	+ 18 48	11.7
OZ	Wolf	"		9	12 08.6	2 14.8	+ 6 25	13.2
PA	Götz	"		10	8 09.2	1 01.5	+ 3 58	12.1
PB	"	"		14	12 43 8	2 50.2	+ 5 37	11.0
PC	"	"		14	12 43.8	3 00.8	+ 9 00	12.0
PD	"	"		15	12 43.8	1 26.3	+ 15 14	12.5
PE	Wolf	"		16	11 30.7	2 54.4	+ 15 54	12.5
PF	"	"		16	13 39.0	2 32.4	+ 9 19	13.0

VARIABLE STARS.

Approximate Magnitudes of Variable Stars Nov. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
T Androm.	0 17.2	+26 26	11.5 *i*	R Camel.	14 25.1	+84 17	12.4*d*
T Cassiop.	0 17.8	+55 14	9	R Bootis	14 32.8	+27 10	8 *i*
R Androm.	0 18.8	+38 1	14	S Librae	15 15.6	—20 2	*s*
S Ceti	0 19.0	— 9 53	11 *d*	S Serpentis	15 17.0	+14 40	12.1*d*
S Cassiop.	1 12.3	+72 5	11.5 *i*	S Coronae	15 17.3	+31 44	13
R Piscium	1 25.5	+ 2 22	10.8*d*	S Urs. Min.	15 33.4	+78 58	7.5*i*
U Persei	1 52.9	+54 20	7.5	R Coronae	15 44.4	+28 28	6
R Arietis	2 10.4	+24 36	9.5 *i*	V "	15 45.9	+39 52	11.5*d*
o Ceti	2 14.3	— 3 26	9.7	R Serpentis	15 46.1	+15 26	9.5*d*
S Persei	2 15.7	+58 8	10 *i*	R Herculis	16 1.7	+18 38	9 *d*
R Ceti	2 20.9	— 0 38	11.2*d*	R Scorpii	16 11.7	—22 42	*s*
U "	2 28.9	—13 35	8.0 *i*	S "	16 11.7	—22 39	*s*
R Trianguli	2 31.0	+33 50	9.5*d*	U Herculis	16 21.4	+19 7	12
R Persei	3 23.7	+35 20	7.5 *i*	W Herculis	16 31.7	+37 32	8.5
R Tauri	4 22.8	+ 9 56	9.5 *i*	R Draconis	16 32.4	+66 58	8.4 *i*
S "	4 23.7	+ 9 44	*f*	S Herculis	16 47.4	+15 7	8 *d*
R Aurigæ	5 9.2	+53 28	*f*	R Ophiuchi	17 2.0	—15 58	9.3*d*
U Orionis	5 49.9	+20 10	10.9*d*	T Herculis	18 5.3	+31 0	9.2*d*
R Lyncis	6 53.0	+55 28	8	R Scuti	18 42.2	— 5 49	6
R Gemin.	7 1.3	+22 52	9	R Aquilae	19 1.6	+ 8 5	12 *d*
S Canis Min.	7 27.3	+ 8 32	8 *i*	R Sagittarii	19 10.8	—19 29	7.5
R Cancri	8 11.0	+12 2	8	S "	19 13.6	—19 12	*f*
V "	8 16.0	+17 36	11 *i*	R Cygni	19 34.1	+49 58	10 *i*
S Hydrae	8 48.4	+ 3 27	9	RT "	19 40.8	+48 32	6.5 *i*
T "	8 50.8	— 8 46	9 *i*	X "	19 46.7	+32 40	6 *i*
R Leo. Min.	9 39.6	+34 58	8	S Cygni	20 3.4	+57 42	*f*
R Leonis	9 42.2	+11 54	9 *d*	RS "	20 9.8	+38 28	7 *i*
R Urs. Maj.	10 37.6	+69 18	12.5*d*	R Delphini	20 10.1	+ 8 47	12.4*d*
R Comae Ber.	11 59.1	+19 20	*u*	U Cygni	20 16.5	+47 35	9 *d*
T Virginis	12 9.5	— 5 29	*u*	V "	20 38.1	+47 47	13 *d*
R Corvi	12 14.4	—18 42	*u*	T Aquarii	20 44.7	— 5 31	11.5*d*
Y Virginis	12 28.7	— 3 52	*u*	R Vulpec.	20 59.9	+23 26	11.5*d*
T Urs. Maj.	12 31.8	+60 2	13 *d*	T Cephei	21 8.2	+68 5	9.5*d*
R Virginis	12 33.4	+ 7 32	*u*	S "	21 36.5	+78 10	10
S Urs. Maj.	12 39.6	+61 38	9.5 *i*	S Lacertae	22 24.6	+39 48	12.5
U Virginis	12 46.0	+ 6 6	*u*	R "	22 38.8	+41 51	13 *d*
V "	13 22.6	— 2 39	*u*	S Aquarii	22 51.8	—20 53	13 *d*
R Hydrae	13 24.2	—22 46	*s*	R Pegasi	23 1.6	+10 0	9.4*d*
S Virginis	13 27.8	— 6 41	*s*	S "	23 15.5	+ 8 22	9.2 *i*
R Can. Ven.	13 44.6	+40 2	11.5*d*	R Aquarii	23 38.6	—15 50	9.7 *i*
S Bootis	14 19.5	+54 16	11 *d*	R Cassiop.	23 53.3	+50 50	*f*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude

13; *i*, that the light is increasing; *d*, that the light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

From observations made at the Halsted, McCormick and Harvard Observatories.

Variable Stars of Short Period not of the Algol Type.

	Minimum.			Maximum.		
		d	h		d	h
X Sagittarii	Jan.	1	4	Jan.	4	1
T Vulpeculae		1	7		2	16
SU Cygni		1	9		2	17
V Velorum		1	17		2	16
V Centauri		2	1		3	12
W Geminorum		2	10		5	1
S Triangulum		2	17		4	19
S Normae		2	19		7	5
R Crucis		3	4		4	13
T Velorum		3	5		4	14
β Lyræ		3	8		6	10
RV Scorpii		3	9		4	19
ζ Geminorum		3	17		8	17
S Crucis		3	20		5	8
T Crucis		4	16		6	17
S Muscae		4	21		18	8
W Sagittarii		5	2		8	2
SU Cygni		5	5		6	13
δ Cephei		5	12		6	21
T Vulpeculae		5	17		7	2
V Velorum		6	2		7	1
V Carinae		6	9		8	13
X Cygni		7	5		13	10
T Velorum		7	20		9	5
X Sagittarii		8	5		11	2
S Crucis		8	13		10	1
Y Ophiuchi		8	15		14	20
R Crucis		9	0		10	9
SU Cygni		9	1		10	9
S Triangulum		9	1		11	3
RV Scorpii		9	11		10	21
β Lyræ		9	19		13	2
T Vulpeculae		10	4		11	13
W Geminorum		10	4		12	19
V Velorum		10	11		11	10
δ Cephei		10	19		12	4
T Crucis		11	9		13	10
T Velorum		12	12		13	21
S Normae		12	13		16	23
W Sagittarii		12	17		15	17
SU Cygni		12	22		14	7
V Centauri		13	1		14	12
V Carinæ		13	2		15	6
S Crucis		13	5		14	17
ζ Geminorum		13	21		18	21
S Muscae		14	13		18	0
T Vulpeculae		14	14		15	23
V Velorum		14	20		15	19
R Crucis		14	20		16	5
X Sagittarii		15	5		18	2
S Triangulum	Jan.	15	8	Jan.	17	10
RV Scorpii		15	12		16	22
TX Cygni		15	17		20	20
W Virginis		16	5		24	10
δ Cephei		16	6		16	15
β Lyræ		16	6		19	8
SU Cygni		16	18		18	2
T Velorum		17	3		18	12
S Crucis		17	22		19	10
W Geminorum		17	22		20	13
T Crucis		18	3		20	4
T Monocerotis		18	23		26	21
T Vulpeculae		19	1		20	10
V Velorum		19	5		20	4
V Carinæ		19	18		21	22
W Sagittarii		20	7		23	7
SU Cygni		20	14		21	22
R Crucis		20	15		22	0
RV Scorpii		21	14		23	0
δ Cephei		21	15		23	0
S Triangulum		21	16		23	18
T Velorum		21	18		23	3
X Sagittarii		22	6		25	3
S Normae		22	7		26	17
S Crucis		22	14		24	2
β Lyrae		22	17		26	0
T Vulpeculae		23	11		24	20
V Velorum		23	13		24	12
X Cygni		23	14		29	19
V Centauri		24	1		25	13
ζ Geminorum		24	1		29	1
S Muscae		24	3		27	14
SU Cygni		24	11		25	19
T Crucis		24	20		26	21
W Geminorum		25	16		28	7
Y Ophiuchi		25	18		31	23
T Velorum		26	10		27	19
R Crucis		26	11		27	20
V Carinæ		26	11		28	15
δ Cephei		27	0		28	9
S Crucis		27	7		28	19
RV Scorpii		27	15		29	1
V Velorum		27	22		28	21
T Vulpeculae		27	22		29	7
S Triangulum		28	0		30	2
SU Cygni		28	7		29	16
β Lyræ		29	4		32	6
X Sagittarii		29	6		32	3
TX Cygni		30	11		35	14
T Velorum		31	1		32	10

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U Cephei.

	d	h
Jan.	1	6
	3	17
	6	5
	8	17
	11	5
	13	17
	16	5
	18	16
	21	4
	23	16
	26	4
	28	16
	31	3

Z Persei.

Jan.	1	5
	4	6
	7	8
	10	9
	13	10
	16	12
	19	13
	22	14
	25	16
	28	17
	31	19

Algol.

Jan.	1	23
	4	20
	7	17
	10	14
	13	11
	16	7
	19	4
	22	1
	24	22
	27	19
	30	15

λ Tauri.

Jan.	4	5
	8	4
	12	3
	16	1
	20	0
	23	23
	27	22
	31	21

R Canis Maj.

	d	h
Jan.	1	7
	2	11
	3	14
	4	17
	5	20
	7	0
Jan.	8	3
	9	6
	10	9
	11	13
	12	16
	13	19
	14	23
	16	2
	17	5
	18	8
	19	12
	20	15
	21	18
	22	21
	24	1
	25	4
	26	7
	27	10
	28	14
	29	17
	30	20
	31	23

V Puppis.

Jan.	2	1
	3	12
	4	23
	6	10
	7	20
	9	7
	10	18
	12	5
	13	16
	15	3
	16	14
	18	1
	19	12
	20	23
	22	10
	23	20
	25	7
	26	18
	28	5
	29	16
	31	3

S Cancri.

Jan.	3	9
	12	20
	22	8
	31	20

S Antliæ.

Period
$7^h\ 46^m 48^s$

	d	h
Jan.	1	6
	2	5
	3	4
	4	4
	5	3
	6	2
	7	2
	8	1
	9	0
	10	0
	10	23
	11	22
	12	22
	13	21
	14	20
	15	20
	16	19
	17	19
	18	18
	19	17
	20	17
	21	16
	22	15
	23	15
	24	14
	25	13
	26	13
	27	12
	28	11
	29	11
	30	10
	31	9

S Velorum.

Jan.	2	17
	8	15
	14	14
	20	12
	26	10

W. Urs. Maj.

Period
$4^h\ 00^m\ 12.8^s$
Jan. 1-31 12^h

RR Velorum.

	d	h
Jan.	2	3
	3	23
	5	20
	7	16
	9	13
	11	9
	13	6
	15	2
	16	23
	18	19
Jan.	20	16
	22	12
	24	9
	26	6
	28	2
	29	22
	31	19

Z Draconis.

Jan.	1	23
	3	8
	4	17
	6	1
	7	10
	8	18
	10	3
	11	12
	12	21
	14	6
	15	14
	16	22
	18	7
	19	16
	21	0
	22	9
	23	18
	25	2
	26	11
	27	19
	29	4
	30	13
	31	21

δ Libræ.

Jan.	1	19
	4	3
	6	11
	8	18
	11	2
	13	10
	15	18
	18	2
	20	10
	22	18
	25	1
	27	9
	29	17

U Coronæ.

	d	h
Jan.	2	1
	5	12
	8	23
	12	10
	15	21
	19	8
	22	19
Jan.	26	5
	29	16

R Aræ.

Jan.	2	11
	6	21
	11	7
	15	17
	20	4
	24	14
	29	0

U Ophiuchi

Jan.	1	13
	2	9
	3	5
	4	1
	4	21
	5	18
	6	14
	7	10
	8	6
	9	2
	9	22
	10	18
	11	14
	12	11
	13	7
	14	3
	14	22
	15	19
	16	15
	17	11
	18	7
	19	4
	20	0
	20	20
	21	16
	22	12
	23	8
	24	4
	25	0
	25	21
	26	17
	27	13
	28	9
	29	5
	30	1
	30	21
	31	18

Z Herculis.

Jan.	1	3
	3	10
	5	13
	7	10

Minima of Variable Stars of the Algol Type.—Continued.

Z Herculis.

	d	h
Jan.	9	13
	11	10
	13	12
	15	9
	17	12
	19	9
	21	12
	23	9
	25	12
	27	9
	29	12
	31	0

SW Cygni.

	d	h
Jan.	3	10
	8	0
	12	14
	17	3
	21	17
	26	7
	30	21

UW Cygni.

	d	h
Jan.	4	2
	7	13
	11	00
	14	11
	17	22
	21	8
	24	19
	28	6
	31	17

W Delphini.

	d	h
Jan.	1	8
	6	3
	10	23
	15	18
	20	13
	25	9
	30	4

VV Cygni.

	d	h
Jan.	2	3
	3	15
	5	2
	6	14
	9	13
	11	0
	12	11
	13	23
	15	10
	16	22
	18	9
	19	21
	21	8
	22	20
	24	7
	25	19
	27	6
	28	17
	30	5
	31	16

VW Cygni.

	d	h
Jan.	8	13
	17	0
	25	10

Y Cygni.

	d	h
Jan.	2	10
	3	20
	5	10
	6	20
	8	10
	9	20
	11	10
	12	20
	14	9
	15	20
	17	9
	18	20
	20	9
	21	19
	23	9
	24	19
	26	9
	27	19
	29	9
	30	19

UZ Cygni.

	d	h
Jan.	24	16

New Variable 156.1904 Ceti.—In *A. N.* 3975 the following estimates of the brightness of this variable are given by Dr. W. Luther, of Düsseldorf, and Mr. P. Moschik, of Königstuhl-Heidelberg, the latter using a Zöllner photometer:

	Mag.			Mag.	
Sept. 20	9.0	Luther	Oct. 14	10.1	Moschik
30	9.7	"	16	10.6	"
Oct. 3	9.8	"	19	10.9	"
" 13	9.9	Moschik			

New Variable Stars 157, 158, 160 and 161.1904.—These are announced by Professor Ceraski in *A. N.* 3971, as discovered by Mme. Ceraski upon the photographs taken at Moscow. Their positions are

No.	R. A. 1855.0			Decl. 1855.0		R. A. 1900.0			Decl. 1900.0	
	h	m	s	°	′	h	m	s	°	′
157.1904	5	53	05.9	+ 46	15.8	5	56	27.0	+ 46	16.1
158.1904	17	48	20	+ 7	52	17	50	30	+ 7	51
160.1994	23	39	15	+ 53	42	23	41	26	+ 53	57
161.1904	19	51	27.4	+ 26	10.2	19	53	19.5	+ 26	17.3

The first is BD. + 46° 1089, magnitude 9.5. In April 1904, according to five observations by Mr. Blajko, it was about 9.2^{m}; in August and September it increased slowly from 10.5^{m} Aug. 15, to 9.5 Sept. 7. The period is unknown.

The second is a faint star, which on several photographs taken in 1899-1904 ranges from 10 to 12½ magnitude.

The third has about the same range of variation.

The fourth is BD. + 26° 3741, magnitude 9.1. The photographs indicate a quite rapid variation between 9.5 and 10.5 in a period of a few days. The star is reddish in color and Mr. Blajko noted it on Oct. 2 and 3 as of 8.2 and 8.8 magnitude.

New Variable Star 159.1904 Pegasi.—This is the one noted last month as discovered by Williams, and as possibly a new star. Investigation appears to indicate that it is a long period variable. Its position has been

determined at Rome and at Arcetri, the mean of four results being R. A. 1904.0 $22^h\ 21^m\ 12^s.61$, Decl. 1904.0 $+ 29° 59' 05.1''$.

New Variable 162.1904 Herculis.—In Circular No. 87 of Harvard College Observatory, Professor Pickering calls attention to this variable discovered by himself with the meridian photometer. He says: "The meridian photometer, like other meridian instruments, is not adapted to the discovery of variable stars. It may therefore be of interest to note the discovery of such an object by the writer, with the 12-inch meridian photometer. On August 23, 1904, while measuring the star BD. + 24° 3419, mag. 9.4, it was noticed that a brighter star, having the photometric magnitude 9.5 and not in the Bonn Durchmusterung, preceded it. An examination the next day, of the photographs of this region, at once showed that the star was a variable of long period having a range extending at least from the magnitude 9.5 to <13. The approximate position for 1855 is R. A. $18^h\ 20^m\ 26^s.0$ Decl. $+ 24° 56'.4$."

Two New Variables 163.1904 Lacertae and 164.1903 Cygni.—These are announced in *A. N.* 3975 by Professor Ceraski. Their positions are

	R. A. 1855	Decl. 1855	R. A. 1900	Decl. 1900
	h m s	° ′	h m s	° ′
163.1904	22 01 15	+ 37 02	22 03 11	+ 37 15
164.1904	21 42 57	+ 43 33	21 44 43	+ 43 46

The first seems to vary between 9.5 and 12.5 magnitude. On a photograph December 5, 1898 it was estimated at 10^m, October 2, 1899, 10^m, August 23, 1900, 9.5^m, October 3, 1900, 11^m. On photographs August 19, 1901, October 1, 1902, and September 7, 1904 the brightness was below 12.5.

The second also varies from 9^m at maximum to 12.5, if not lower, at minimum, but no definite minimum has been observed.

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

	d	h		d	h		d	h		d	h
Jan.	1-7	14	Jan.	8-14	15	Jan.	15-22	16	Jan.	23-30	17

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

	d	h		d	h		d	h		d	h
Jan.	1	10	Jan.	9	14	Jan.	17	18	Jan.	25	22
	2	10		10	14		18	19		26	23
	3	11		11	15		19	19		27	23
	4	11		12	15		20	20		29	0
	5	12		13	16		21	20		30	0
	6	12		14	17		22	21		31	1
	7	13		15	17		23	21			
	8	13		16	18		24	22			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum

	d	h		d	h		d	h		d	h
Jan.	2	0	Jan.	9	21	Jan.	17	17	Jan.	25	14
	3	3		11	0		18	20		26	17
	4	6		12	3		19	23		27	19
	5	9		13	6		21	2		28	22
	6	12		14	8		22	5		30	1
	7	15		15	11		23	8		31	4
	8	18		16	14		24	11			

GENERAL NOTES.

Gold Medal Awarded for Dr. Brooks' Cometary Discoveries.—Hobart College, Geneva, N. Y., and Dr. Brooks, Professor of Astronomy in the College, have both been honored at the St. Louis World's Fair.

The International Jury have awarded a bronze medal to Hobart College for its general exhibit in higher education, representing all departments; and to the astronomical exhibit, prepared by Professor Brooks, a special gold medal. The distinguishing feature of the Astronomical exhibit, and which was warmly commended by the Jury, was a photographic collection of all the comets, now twenty-four in number, discovered by Professor Brooks. Eleven of these discoveries, as many of our readers know, were made at the Red House Observatory, and thirteen at the Smith Observatory, Geneva, N. Y.

The Latitude and Longitude of the University of Wooster Observatory, Wooster, Ohio, have been made recently by W. H. Wilson and are as given below:

Lat. = 40° 48′ 38″ North
Long. = 5^h 27^m $44^s.3$ West of Greenwich.

Signaling to Mars.—Mr. Larkin of Mt. Lowe has written a letter to the *Examiner* of Los Angeles, California about signaling to the planet Mars. He makes a good point, and one that is often overlooked, when he says that the dark or night side of two planets are never turned toward each other. When the Sun is between them it is day on the side of Mars which is towards us, and also day on the side of the Earth which is towards Mars. When they are on the same side of the Sun it is day on Mars, when night on the Earth and for this reason they could not see our signals.

This should make it apparent that the task of signaling to Mars is a more difficult one than the most hopeful theorist has probably considered. All this is under the supposition that the Martians (if there are such) are beings like ourselves. If they are not like us, we cannot guess what they are like.

Rock Pressure at Great Depths.—From recent correspondence found in *Nature*, Oct. 20, 1904, p. 602, it appears that some prominent physicists have been considering the rock pressure that would effect the drilling if it were extended in the Earth to the depth of twelve miles.

In this matter Mr. Charles A. Parsons made reference to "the Philosophical Transactions of the Royal Society of England, part i, 1882, in which the great shearing stresses that are thrown on the Earth's structure by the weight of mountain ranges on elevated continents and the great depths of the sea are exhaustively treated." Mr. Parsons goes on to say:—"I would only point out that such stresses have been endured for long epochs, and that in view of the established fact that rocks are viscous, it is clear that much greater stresses could be sustained for the comparatively short time necessary to complete a deep shaft boring.

It would however be interesting to subject a cylinder of granite or quartz rock, carefully fitted into a steel mould and having a small hole bored through its center, to a shrinkage, say 100 tons per square inch, and see what shrinkage in the hole would result, or a hole might be bored into the specimen through an aperture in the mould while subjected to the pressure. This pressure would correspond to a depth of about thirty-eight miles.

This study is one of great interest both to the physicist and to the astronomer.

Orionids at University of Va.—The Orionid meteors were observed here on Oct. 14, 16 and 18 by myself, and on Oct. 18 also by Mr. J. Brookes Smith and Mr. J. P. Smith of this University, observing from Dudley's Mt., distant eight miles to the S. W. The following tables give the result of the counts:

Date			Orionids.	Others.	Total.	Remarks.
	d	h m — h m				
1904	Oct. 14	13 22 — 14 0	3	3	6	Fairly clear.
		14 0 — 15 2	2	15	17	" "
	Oct. 16	12 23 — 13 23	5	8	13	Very clear
		13 23 — 14 23	6	11	17	" "
		14 49 — 15 29	6	1	7	" "
	Oct. 18	11 16 — 12 0	2	1	3	Moon and smoke.
		12 0 — 13 0	2	3	10	" "
		13 0 — 14 0	7	7	14	" "
		14 0 — 15 0	12	5	17	Clear.
		15 0 — 16 0	11	5	16	"
		16 0 — 17 16	12	3	15	"
Total			68	67	135	

Observer C. P. O.

	d	h m — h m				
1904	Oct. 18	11 56 — 13 0	3	2	5	Moon.
		13 0 — 14 0	2	4	6	"
		14 0 — 15 0	11	6	17	Clear.
		15 0 — 16 0	9	2	11	"
		16 0 — 16 22	7	2	9	"
		Times not recorded	0	12	12	
Total			32	28	60	

Observer J. B. S.

	d	h m — h m				
1904	Oct. 18	11 52 — 13 0	4	1	5	Moon.
		13 0 — 14 0	3	2	5	"
		14 0 — 15 0	15	2	17	Clear.
		15 0 — 16 0	6	3	9	"
		16 0 — 16 32	9	3	12	"
		Times not recorded	0	7	7	
Total			37	18	55	

Observer J. P. S.

The shower was remarkable for the small number of bright meteors seen, and on the night of the maximum it was less conspicuous than for several years past, except in 1902 when moonlight interfered. The radiants of the Orionids on the several nights were as follows:

Date.	α	δ	No. Meteors.	Observer.
1904 Oct. 14	97°	+ 17°	4	C. P. O.
16	93	+ 18	6	C. P. O.
18	92	+ 16	22	C. P. O.
18	91	+ 16	11	J. B. S.
18	92	+ 16	5	J. P. S.
18	94	+ 19	4	J. P. S.
18	90	+ 13	4	J. P. S.

Only meteors in favorable positions and well observed were used to determine the above radiants. On Mr. J. P. Smith's map for October 18, there are three distinct radiants, all sharply defined. On the maps of the other observers for the same date, the single positions given satisfy most of the meteors well, but there are a few besides which would radiate from both the lesser radiants.

The shift in the radiants as shown by my observations is small but decided.

However, unfortunately, those for October 14 and 16, depend on too few meteors to be conclusive, though the probability is strong that a real change has been detected.

The most brilliant meteor was No. 4341, seen at 13^h 14^m 20^s on October 18. It was fully equal to Venus, of an orange color, but did not belong to the Orionid group.

On Oct. 18 about thirty-five meteors were observed at both stations, and the real paths of a large proportion of them will be computed and the results communicated later. CHARLES P. OLIVIER.

STUDENTS OBSERVATORY,
University of Va.

British Astronomical Association Report of a Year's Work. —From the last report covering a period from Oct. 1, 1903 to Sept. 30, 1904, some interesting facts are learned. At the beginning of the year, the association had a membership of 1,056, at the end of the year it is 1,007, a loss of forty-nine members, chiefly from deaths and resignations. This large and active association has kept up its good record in the matter of publications. In addition to the usual issue of the "*Journal*" of the association, it has published several creditable memoirs. Volume XI. is now complete which is occupied with the work of the Variable Star section. Part 2, of Volume XII of the Solar section, part 3, of the Jupiter section and part 1, Volume XIII of the Meteor section. The observations of the Solar section were concerned with the great sun-spot of Oct. 1903, and the simultaneous displays of aurora borealis, but the chief work of observation and of record has been on the life histories of sunspots, including visual, magnetic and spectroscopic features.

From these observations it appears that a general disturbed state of the Sun corresponds to a period of magnetic storms, but no relation between isolated spots or prominences and magnetic disturbances yet appears. The connection is not one of cause and effect.

In the spectra of sun-spots, the prevalence of titanium flutings in the spectra of Secchi's third type would seem to suggest that such stars are suns having very spotted photospheres. Vanadium and titanium are found to be the elements whose lines are most affected in sun-spots.

The work of the Lunar section has been mainly to observe for changes in the surface markings of the Moon. Professor W. H. Pickering's work during the last year has awakened interest in this section. Its observations are especially directed to suspected changes in the floor of Plato.

The observations of the Mercury and Venus section were limited. In the work on Mercury only two nights of fine definition were found. Then no markings were seen on the planet's surface; at another time a shaded, but a fairly well defined area was seen. The seeing at the time these observations was esteemed good. The terminator on Mercury was much less shaded than on Venus under almost similar conditions.

In the report of the Saturn section attention is called to the observation of the new white spot seen first almost simultaneously by Mr. Barnard of Yerkes Observatory and Mr. Denning of England. It was situated in about 30° north latitude of the planet. The spot was unusually far from the equator, for such a marking and it was at once observed very carefully and very generally to determine the period of rotation of the planet. The result obtained from several sources, in which there was close agreement, was ten hours and thirty-eight min-

utes for the rotation-time of the planet in that latitude. The period heretofore accepted is ten hours and fourteen minutes, which was obtained by observing spots near the planet's equator. The inference is that portions of the planet's surface in different latitudes have different times of rotation. Mr. Denning observed Saturn for sixty-five nights.

The comet section has had little to report because, within its year, only one comet was discovered and that was found April 16, by Professor Brooks of Geneva, in this country. That comet is remarkable for having been third in the list of known comets, as to perihelion distance from the Sun. At the time of discovery it had passed its perihelion place, and on this account the time for observation of it was limited.

Tempel second periodic comet is now due, but it has not yet been seen.

Encke's comet has been twice photographed at Heidelberg by A. Kopff on Sept. 11 and 17 with an expcsure of three and a half hours. The elements and ephemeris are known.

The meteoric section reports that the Perseids of August were weaker than usual, although some of the nights for observation were very favorable. Brilliant meteors appeared in January, February, March, April and July and six in August.

The variable star section has had a good working list of forty-seven stars in all. It has also taken up recently observations of certain selected areas of the Milky Way, with a view to the detection of new variables.

The association has a photographic section, a library and a lantern slide department. Its work as a whole commands the attention of astronomers everywhere.

The Life History of Radium.—This most interesting substance has attracted the attention of scholars all over the world. Its many curious properties are likely to touch and influence every science, and astronomers are on the lookout for a large share. In the *Journal of the Franklin Institute* for November, the following brief account of the life history of radium is given:—

"The view that uranium is the parent substance of radium was advanced by Rutherford and Soddy on the ground that it is one of the few elements having a higher atomic weight, that it is the main constituent of radium ores, and that the proportion of radium in good pitchblende corresponds roughly with the ratio of activity of radium and uranium. An examination of a number of specimens of uranium salts purchased from seventeen to twenty-five years ago showed that these all contained a larger proportion of radium than the more modern specimens. This result is in accordance with the theory enunciated by Rutherford and Soddy, but may easily be due to modified methods of preparation. F. Soddy (*Nature*, 70, p. 30, May 12, 1904), tsates that a kilogram of uranium nitrate was purified until the proportion of radium present was less than 10^{-13} gram as tested by the maximum amount of accumulated emanation. At the end of twelve months the amount of accumulated radium was certainly less than 10^{-11} gram instead of the 5×10^{-7} gram calculated from the ratio of the radio-activities of radium and uranium. The quantity of radium produced was therefore less than one ten-thousandth part of the theoretical quantity, and this result practically settles, in a negative sense, the question of the production of radium directly from uranium. It is, of course, possible that intermediate substances might exist, and that radium would only be produced at a later stage, but there is no experimental evidence in support of this view."

Jupiter's Third Satellite Seen With the Naked Eye.—In the *Astronomische Nachrichten* No. 3975, Dr. J. Möller, of Elsfleth, recounts an

extraordinary observation of Jupiter's third satellite. He says: "On November 1, 1903 while on board a sailing vessel, in a calm ocean, in north latitude 15° and west longitude 137°, at seven o'clock in the evening (about 16^h Greenich mean time) I saw a faint little star close to Jupiter. Before I could call the attention of other of the ship's passengers to the phenomenon, the fourth officer taking an azimuth of Jupiter with the azimuth-compass called to me that he saw a little star close to Jupiter. Field-glass and Nautical Almanac left no doubt that it was the third satellite. The fourth moon, situated farther off on the other side, could not be distinguished with the naked eye. We were at the limit between an unusually extensive storm area and the district, just entered on that day, of the northeast passage, where according to my experience the air is apt to be especially transparent."

Leonid Meteors.—Two observers watched the sky in the region of the constellation of Leo on the morning of November 15th, from 2:35 to 4:45 Eastern Standard time, but only twenty-eight Leonids were seen. The sky was cloudless, the Milky Way bright.

With a single exception, none of the meteors seen was brighter than the second magnitude, and several were very faint. The faint ones were noticeably orange in color, the brighter ones a bluish white. They were very swift, with short trails so that it was difficult to determine their path with accuracy.

The following is a summary of the count of meteors seen:

Time.	Leonids.	Non-Leonids.
2:35-3:00	2	0
3:00-3:30	6	5
3:30-4:00	8	10
4:00-4:30	7	5
4:30-4:45	5	2
Total	28	22

ANNE SEWELL YOUNG.

MOUNT HOLYOKE COLLEGE,
SOUTH HADLEY, Mass.

The Eros Parallax Campaign.—Circular No. 11 of the International Astrophotographic Conference of July 1900, a quarto volume of over 400 pages, has just come to hand, having been published at Paris, Oct. 1, 1904. It contains the results of micrometric measures of the planet Eros, made at the observatories at Marseilles, Padua, of heliometer measures at Bamberg, and of photographic observations of the planet or of the comparison stars at Algiers, Catania, Northfield, San Fernando, Paris and Toulouse. There is also a very important paper by Mr. Tucker of Lick Observatory containing a normal catalogue of the stars of reference based upon the published meridian observations of thirteen observatories. In an appendix is given a list of researches and observations connected with the Eros work which have been published elsewhere than in the Circulars of the Conference.

In his introductory note Professor Loewy, the Director of the Observatory of Paris, speaks with gratification of the great quantity of material which is now at hand for the parallax problem, and of the great accuracy which has been so generally attained by the forty observatories coöperating in this work. He expresses the hope that the next Circular, No. 12, will contain all of the observations of real value now remaining unpublished.

The following table gives a résumé of the photographic observations which are

contained in Circulars 10 and 11. From this it will be seen that 811 plates have been measured yielding 522 positions of the planet Eros and also extremely accurate places of about 3000 stars scattered along a part of the apparent path of Eros. These star places, aside from contributing to the problem for which they were directly intended, have a permanent scientific value.

Three lists of stars are referred to in the table:

First, the stars of reference (*étoiles de repère*). These were selected at the beginning of the campaign, to serve as reference stars in measuring the photographic plates. They were scattered along the path of Eros so that ten or twelve might be found upon any photograph taken. Their places were measured with all possible accuracy with the meridian circles at thirteen observatories. The normal positions obtained from thirteen sets of observations form the basis of the photographic measurements. The photographs in turn give revised positions of these same stars as well as of other fainter stars.

Second, the comparison stars (étoiles de comparaison) which were used in the micrometric measures of Eros made with the great telescopes at several observatories. These stars were generally faint, running even as low as the thirteenth magnitude in some cases. Their positions have been determined so far as possible from measures of the photographs, special series of plates being taken for this purpose at some of the observatories.

Third, in order to make sure of having a sufficient number of comparison stars near the planet, several observatories adopted the plan of measuring at the same time with the images of Eros, those of all the faint stars within a space 20′ square, having the planet in its center.

RÉSUMÉ OF THE PHOTOGRAPHIC OBSERVATIONS, RELATING TO THE DETERMINATION OF THE SOLAR PARALLAX, CONTAINED IN CIRCULARS NOS. 10 AND 11.

		Stars of Reference.		Stars in 20′ Zone.	Comparison Stars.		Planet.
Observatory	No. of Plates.	No. of Stars	No. of Obs.	No. of Obs.	No. of Stars.	No. of Obs.	No. of Obs.
Algiers	112	631	1648	......	929	1944	......
Bordeaux	52	232	711	676	306	1068	52
Catania	47	434	573	2272	397	534	......
Northfield	68	286	557	......	22	76	68
Paris	284	505	3682	2488	748	4688	284
San Fernando	166	662	2930	1834	778	1720	76
Toulouse	82	463	2481	612	1530	2641	42
Totals	811	671	12582	7882	962	12671	522

Special Time Signal.—In speaking of the special time signal sent out from the Naval Observatory at Washington, Sept. 8, 1904, during the session of the National Geographic Congress at that place, we said, on p. 615 of our last issue, four lines from bottom: "The long intervals in a few cases are perplexing if the wire connection was continuous. If messages were repeated, at any point in transmission to Mauritius or Rio Janeiro, for example, an interval of a few minutes might be necessary."

Superintendent C. M. Chester of the Naval Observatory, upon our request, had the kindness to send us a type-written copy of a report of the results of the special time-signal, for use in this publication. The telegraphic replies which were timed covered two points: One, a message of greeting to the Geographic Congress at Washington from many different points all over the world, the other, a message

intended to give the interval of time approximately, that would be required to send a time-signal to all countries in the world, if there were but one system of time distribution in use. The data that we had in hand from Washington did not clearly distinguish in all cases between these two messages; so we were in doubt in some cases, and made the statement above referred to, in order to cover that point.

In a letter from Superintendent Chester under date of Nov. 5, he speaks of the delay incident to manual repeating over each branch of a long cable line, and says that a time-signal from Washington around the world would require sixteen repetitions, as follows: New York, Azores, Lisbon, Gibralter, Alexandria, Suez, Aden, Bombay, Madras, Singapore, Hongkong, Manila, Guam, Midway, Honolulu and San Francisco.

It is very evident that manual repetitions of a message would consume time, and the great wonder is that all the messages reported were conveyed so far, in such way in so short a time. We did not mean to convey the idea that any of these messages were so accurately timed as to give the true time interval of the actual transmission of a message between any two points of the vast territory covered. Any one acquainted with this kind of work would know that such a thing would be impossible under the circumstances.

The report of this special time-signal that appeared in the *National Geographic Magazine* for October, p. 411, gives information on the point of time-intervals between Washington and other points which is a fairly close approximation in regard to time of transmission when repeaters and "wave and armature movements are included in the calculation. We copy some of these results:

Source.	Place.	Interval.	
Cordoba Obs'y	Argentina, S. A.	2.	seconds
National "	Tacubaya, Mexico	0.36	"
McGill "	Montreal, Canada	0.10	"
Meteorological Obs'y	Toronto	0.23	"
Harvard Obs'y	Cambridge, Mass.	0.10	"
Lick "	Mt. Hamilton, Cal. (fast)	0.24	"
Goodsell "	Northfield, Minn.	0.10	"
Washburn "	Madison, Wis.	0.30	"
Chamberlain Obs'y	Denver, Colo.	0.07	"
Laws Obs'y	Columbia, Mo.	0.54	"
Allegheny Obs'y	Allegheny, Pa.	0.42	"

In our previous article, we inadvertently omitted to give the time interval at the National Observatory at Tacubaya, Mexico, and we wrongly placed that important observatory at the City of Mexico. It is located at Tacubaya, Mexico.

We have recently received a letter from the Director of the National Observatory at Tacubaya showing the extreme care used in getting the time interval given above. He also calls attention to our report of the time-interval from his observatory on last New Year's eve. It was reported from the *Washington Circular* as one minute and nineteen hundredths seconds. The true interval was 0.19 seconds. It was probably a misprint in the *Washington Circular.*

Halley's Comet.—Your readers may be interested in the quotations given below:—

"The first comet that has been calculated solely from European observations was that of 1456, known as Halley's comet, from the belief long, but erroneously entertained, that the period when it was first observed by that astronomer was its first and only well attested appearance." (*Cf.* Humboldt's "Cosmos"

translated by E. C. Otté, vol. 1., pp. 84, 85, note, London, 1901; also "Kosmos," in German, Erster Band, Anmerkungen, pp. 389, 390 (12), Stuttgart, 1845.)

"Halley knew that he could not himself live to witness the fulfillment of his prediction, but he says: 'If it [the comet] should return, according to our predictions, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman.' This was, indeed, a remarkable prediction of an event to occur fifty-three years after it had been uttered. The way in which it was fulfilled forms one of the most striking episodes in the history of astronomy. The comet was first seen on Christmas Day, 1758, and passed through its nearest point to the Sun on March 13, 1759. Halley had then been lying in his grave for seventeen years, yet the verification of his prophecy reflects a glory on his name, which will cause it to live for ever in the annals of astronomy." (*Cf.* 'Great Astronomers,' Sir Robert S. Ball; also *Good Words*, xxxvi., pp. 753, 4.)

"It is to be hoped, the present age will not forfeit the character of impartiality; but that all the world will now unite in doing justice to such distinguishing merit." (*Cf.* 'Two Lectures on Comets,' John Winthrop, Appendix, p. 40, Boston, 1759.)

Halley, in the use of the word "this" (the original version is not in the Chicago libraries) undoubtedly referred not to his discovery of the comet of 1682, itself, but to his discovery of its identity, for as is well known, he had calculated the orbits of twenty-four comets, among which he fonnd at least three that from the similarity of their elements, he concluded to be identical with each other and with the one of 1682 which now so justly bears his name.

EUGENE FAIRFIELD MCPIKE.

CHICAGO, Illinois,
Nov. 9th, 1904.

Revision of the Cape Photographic Durchmusterung.—A part of the annals cf the Cape Photographic Durchmusterung Vol. IX. has been published, consisting of divisions I. II. and III. These parts are on An Examination of questions which have arisen from a comparison of other star catalogues with the C. P. D.; Observations of Variable Stars; and Errata of southern Star Catalogues. The first part is useful in giving information about the disagreement of catalogues in regard to star magnitudes. This fact gives difficulty to those who want to know whether or not a given star is variable. The stars of the Cordoba Zone Catalogue, some of them, suggest an interesting field for study. A number of them can no longer be found, some of them are variables, and some of them turn out to be observations of minor planets, but there is no explanation for the disappearance of so many of them. Gould was an accurate observer, and Mr. Innis who has had this work in charge has confidence in his work, and has therefore given the more careful attention to the study of comparisons in which the Cor-doba Catalogue was concerned. As a result new variables have been discoveredand long period variables suspected.

In regard to Gilliss' Southern Circumpolar Catalogue, it is said that a considerable number of these stars could not be found by the aid of a 7-inch telescope. The explanation given by the Washington authorities at the Naval Observatories was that most of the discrepancies are misprints or errors which admit of corrections now made. The lists of the missing stars and the errors are given in the volume.

The part of this volume devoted to variable stars is interesting and useful in several ways. It is a record of work at the Cape covering a period from 1896 to

1902. Lists of suspected variables are easily made, but it is quite another thing to find out the reasons for discordances. That means continued study for a longer time. The curves and the star charts accompanying each variable is just what the observer needs for his information in testing the conclusions reached by those who have made a study of the same variables.

The considerable lists of errors that have been compiled for this volume is another veiy serviceable part of it.

On Some Results Obtained by the D. O. Mills Expedition to the Southern Hemisphere.*—In the extended program for determining the velocity of the solar system through space by means of the radial velocities of the stars, which has been in progress at the Lick Observatory for seven years, the need had long been felt for extending the scope of the work so as to cover the entire sky. For a full and rigorous solution of the problem it seemed absolutely imperative that the neglected portion of the southern sky within 60° of the South Pole be included. The generosity of Mr. D. O. Mills made it possible to supply this deficiency. As is well known, the equipment sent to South America consisted of a powerful three-prism spectrograph attached to a 37-inch reflector of the Cassegrainian form. The Observatory is situated on the summit of Cerro San Cristobal in the city of Santiago, Chile, and definite work on the program was commenced on September 11, 1903, by Astronomer W. H. Wright and Dr. H. K. Palmer. Up to June 1, 1904, three hundred and eight successful spectrograms had been secured.

One of the most interesting "by-products" of the spectroscopic determination of the solar velocity, as carried out at Lick Observatory, has been the discovery that at least one in every seven or eight of the brighter stars are spectroscopic binaries. Similar results are being secured at the Southern Station, and in *Lick Observatory Bulletin*, No. 60, Mr. Wright announces the binary character of five stars: β Doradus, *W* Velorum, λ Carinal, κ Pavonis, and τ Sagittarii.

Mr. Wright has also succeeded in measuring the difference in radial velocity of the components of the visual binary α Centauri. From a combination of these data with the visual elements, as is well known, the parallax can be obtained with great accuracy and without the assumptions as to the great distance of the comparison-stars used which must be made in heliometrically determined parallaxes.

The values secured are:—

$$\pi = 0''.76 \pm 0''.03$$
$$a = 3\ .46 \times 10^9$$
$$m_1 + m_2 = 1\ .9$$

Gill and Elkins's value from heliometer observations was $0''.75 \pm 0''.01$, relative to the comparison-stars used, which were of average magnitude 7.6.

H. D. CURTIS.

An Introduction to the Study of Spectrum Analysis.—W. Marshall Watts of London is the author of this new elementary text for elementary study of Spectrum Analysis. It is published by Longmans, Green & Company 39 Paternoster Row, London, and New York. The purpose of this new book is to fill the place of a text-book preparatory to the heavier standard books that deal with spectroscopy too much in detail, for the wants of professional investigators. It aims to meet the wants of students at work in this new and delightful of study: It explains how a spectrum is produced; the flame spectra, and those obtained by electricity, absorption spectra, and by the electric arc. The production of the diffraction spectrum and the measurement of wave-lengths with the many cuts for illustration is a valuable chapter. The study of the dark

* Abstract of *Lick Observatory Bulletin*, No. 60.

lines by absorption and the Fraunhofer lines of the solar spectrum is another that fills its place well. The spectra of the stars and nebulae are briefly and plainly described and amply illustrated. We are interested to see so much said in a clear and terse way. The illustrations of the bright nebulæ which astronomers know so well do not seem to the writer over abundant for the general student of this branch; for he is not expected to be very familiar with them.

The spectroscopic study of the Sun is another theme of the greatest interest at the present time. In the twelve pages devoted to this, there are fourteen cuts, most of them good illustrations for the points to be shown by them. In another chapter new stars, double stars and comets are grouped, and their spectra shown. The illustrations are from photographs of the best, recent work.

The concave grating and the spectra secured by this most helpful means makes one of the most interesting chapters which the book contains. The writer has marked this for another and a more careful reading. The last three chapters are occupied with the relations between the different lines of a spectrum and between lines of the spectra of allied elements; band spectra, spectra of compounds; and the Michelson Echelon diffraction grating. The reading of these chapters requires thought and study.

This new book has value as a reference book for its full catalogue of spectra. Its tables are those of the Rowland standard wave-lengths.

Professor Watts has prepared a very much needed book and he has done his work admirably.

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